Thermoforming Quarterly®

A JOURNAL OF THE THERMOFORMING DIVISION OF THE SOCIETY OF PLASTICS ENGINEERS

SECOND QUARTER 2015 ■ VOLUME 34 ■ NUMBER 2

The New Logic of Workforce Development

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Thermoforming Quarterly®

A JOURNAL PUBLISHED EACH CALENDAR QUARTER BY THE THERMOFORMING DIVISION OF THE SOCIETY OF PLASTICS ENGINEERS

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Cover Photo: *Future thermoformers at the Maac machine at Kettering University. (Photo courtesy of Kettering University)*

Mark Strachan

Picking Up the Pace

If it seems like this Q2 edition of *Thermoforming Quarterly* is coming quickly on the heels of Q1, then you would be a discerning reader of our flagship publication. We have a slightly accelerated calendar this year because the annual Thermoforming Conference will take place earlier than usual (August 31 – September 2).

While our colleagues in the Northeast are finally seeing their sidewalks and driveways after a harsh and snowy winter, the rest of us continue our work across the thermoforming industry. As I have written on these pages before, we are all part of a broader industry ecosystem: what happens upstream with novel resin development leads to technological innovation in sheet extrusion technology (see p. 18); thermoformed sheet with tighter tolerances reduces the margin for error in material distribution, so machinery and tooling become more precise with servo motors, faster drives and more computing power for data acquisition and trending analysis. For those who wandered the halls at NPE, you would have seen evidence of the players in this ecosystem, from extrusion and thermoforming OEMs, to moldmakers, to sheet and resin suppliers, to auxiliary component suppliers where many incremental improvements in technology contribute to the evolution of our industry.

That said, there was a dearth of thermoforming papers presented at the ANTEC conference at NPE. Compared to other sections and divisions of SPE, a total of 4 papers is a paltry return, especially when you consider how many applications and end-uses there are for thermoforming. Perhaps we can debate the reasons for this among ourselves. In this issue of *TQ*, we offer our readers one of the submissions: "On the Potential of Stereo Digital Image Correlation (SDIC) in Thermoforming." Like other simulation technologies, SDIC offers users the ability to model what happens to plastic before incurring costs by putting sheet into a machine. Adoption rates are still quite low for thermoforming simulation software, though sensors and PC controls continue to offer new data to those processors who want it.

In keeping with our mandate to educate the next generation of industry professionals, the Thermoforming Division sponsored the t-shirts for The Plastics Race® at NPE (see p.12). This high-profile event drew attention from the national plastics media and the leadership of SPE and SPI. If we are all going to be in the same boat when it comes to developing talent, at least we can be sure that a large thermoformed kayak is a safe option!

In this issue we mark the passing of a true industry pioneer, Jack Pregont, founder of Prent Corporation (see "In Memoriam" on p. 34). His legacy is evident around the globe as the company he founded is now present in multiple US states and 5 countries in Europe, Asia and Central America. May he rest in peace.

New Members

Vikas Bharduwaj
Pluss Polymers Pvt. Ltd.
Gurgaon, Haryana

Deepak Doshi
Machinecraft
Mumbai, Maharashtra

Rushabh Doshi
Machinecraft
Mumbai, Maharashtra

Gert Claasen
Safripol Pty. Ltd.
Bryanston, South Africa

Aaron Butterbrodt
GE Healthcare
Milwaukee, WI

James Harvey Solegear
Bioplastics
Chandler, AZ

John Wagner
Bayly Inc.
Thomasville, GA

Henry Sommer
Newell Rubbermaid
Atlanta, GA

Mark Mason
Hanwha Azdel
Forest, VA

George Gatlin
INVEMA
Doral, FL

Glenn Hilton
Bayer Material Science
Gibsonia, PA

Jeffrey Beard
BES Packaging Corporation
Elk Grove Village. IL

Thermoforming in the News

Two Metro Area Companies Among Manufacturer of the Year Winners

By Rick Barrett of the *Journal Sentinel* (Milwaukee, WI)

February 26, 2015 — Two companies from metropolitan Milwaukee won top awards at the Wisconsin Manufacturer of the Year banquet held Thursday night at the Pfister Hotel.

Husco International Inc. of Waukesha and General Plastics Inc. of Milwaukee were grand award winners, along with Seats Inc. of Reedsburg; Spectrum Industries of Chippewa Falls, and E.K. Machine Co. of Fall River. Ellsworth Cooperative Creamery of Ellsworth won a marketplace opportunity award. Universal Acoustic & Emission Technologies of Stoughton won an employee development and commitment award.

The annual competition is sponsored by the state's largest business lobby, Wisconsin Manufacturers & Commerce, along with the accounting firm Baker Tilly and law firm Michael Best & Friedrich.

"Our state's manufacturing sector is one that is consistently testing limits, questioning processes and breaking boundaries. Their successes are a result of their passion for and dedication to the industry, their customers, their employees and Wisconsin as a whole," said Tod Linstroth, senior partner of Michael Best & Friedrich.

Husco has tripled its sales in the last five years, according to Wisconsin Manufacturers & Commerce. The company is a components supplier for vehicle makers such as Ford Motor Co., and also supplies hydraulic and electro-hydraulic controls for off-highway applications.

"They firmly believe in supporting their surrounding communities through various methods including providing financial assistance to a large and diverse group of nonprofits. Husco and its owners donated over $7 million in 2014," WMC said.

General Plastics Inc. is a custom provider of engineered thermoplastic materials, from polycarbonate to polyethylene. Last fall, the company announced plans to expand its manufacturing plant and add 15 jobs. When General Plastics' current owner, Bob Porsche, purchased the company in 1987, it had eight full-time employees. Today, it has more than 70 full-time employees, and the company has completed two expansions over the past 27 years.

Fabri-Kal Announces New Manufacturing Facility For Burley, ID

By Paul Johnson

March 19, 2015 Burley, Idaho (KMVT-TV / KSVT-TV) — Plans for a new manufacturing plant were revealed this Thursday afternoon when Fabri-Kal announced they were coming to Burley. The company is a leading provider of plastic foodservice and custom thermoformed packaging solutions.

A news release issued by Fabri-Kal indicates they will break ground on March 30 and be fully operational in the fall of 2015. "We appreciate Fabri-Kal's investment in our state, including the future career opportunities it will create for Idaho families in the Magic Valley," said Idaho Governor C.L. "Butch" Otter. "On behalf of the state of Idaho, Cassia County, and City of Burley, we look forward to being a partner in helping the company achieve success for many years to come."

The $50 million project will result in a new 100,000-square-foot design and manufacturing facility. The facility will expand Fabri-Kal's footprint in plastics thermoforming and house initiatives to add to the existing Greenware product line using a new plant-based fiber material.

"Development of the new manufacturing facility in Idaho is a strategic effort that supports Fabri-Kal's growth plans, continued focus on innovation and providing solutions to our customers and partners," said Mike Roeder, president and chief operating officer at Fabri-Kal.

"We are excited to expand our plastic thermoforming footprint west of the Rockies while growing our material offering at the same time," said Chuck Garlock, vice president of sales and marketing at Fabri-Kal. "The new plant-based ag-fiber material will become part of Fabri-Kal's Greenware packaging line and support our commitment to providing sustainable packaging solutions in the foodservice, consumer product and retail markets."

The new manufacturing facility will employ approximately 50 people upon opening and an additional 100 people within the next five years. The building will maintain Fabri-Kal's high quality and manufacturing standards with plans to be ISO (International Organization for Standardization) and FSSC 22000 (Food Safety System Certification) certified within one year. The facility will reflect Fabri-Kal's mission to be a leading provider of sustainable packaging solutions, with half of operations focused on expanding the brand's footprint in plastics thermoforming, and the other half of operations focusing on new, innovative product solutions utilizing the new fiber material.

"We look forward to building our new facility in the community of Burley, and would like to extend our appreciation to the state of Idaho and local agencies in Burley for their support in developing this project," said Gary Galia, executive vice president of finance, Fabri-Kal Corporation.

Kuraray Completes Acquisition Bio-Based Barrier Film Specialist Plantic

From *BioPlastics magazine (online version)* & *www.kuraray.co.jp*

April 10, 2015 — Kuraray has announced that is has now successfully acquired 100% of the shares in Plantic Technologies Limited, an Australian manufacturer of biobased barrier films.

In advance of the acquisition, Kuraray had already concluded a contract with Plantic to be the exclusive distributor of Plantic in the Japanese and South Korean markets. The company was also promoting the biomass-based barrier material Plantic film in Japan.

The acquisition of Plantic enables Kuraray to provide barrier materials which meet the increasing global demand of bio-based food packaging materials. This is in line with Kuraray's corporate mission "we in the Kuraray Group are committed to opening new fields of business using pioneering technology and contributing to an improved natural environment and quality of life". As a world leading producer of barrier materials, Kuraray will further develop its business through the addition of Plantic's best in class bio-based barrier material. In addition, there are significant synergies between Kuraray's existing barrier business and Plantic's bio-based barrier technology which will drive new applications. Further, Kuraray's market leading technology and global sales network is expected to accelerate the development and expansion of a barrier material business, including Plantic's technology in Europe, USA and Asia.

Plantic is a global leader in bio-based barrier materials. Plantic's proprietary patented polymer technology is based on the use of high-amylose starch, a material derived from annual harvesting of specialized non-GM (hybrid) starch. Plantic's business has grown rapidly since the launch of its environmentally friendly and organic material with the gas barrier property. Its film is used in a broad range of products in the barrier packaging sector and is supplying major supermarkets and brand owners on three continents Plantic(Australia, North America and Europe) in applications such as fresh case ready beef, pork, lamb and veal, smoked and processed meats, chicken, and fresh seafood and pasta applications.

In the Australian market, Plantic film is well known and is being used by a major supermarket. In the United States, the largest meat consuming country, Plantic has commenced supply to a number of brand owners and retailers and Kuraray will further develop Plantic's business, including the potential establishment of a production base or an alliance with third parties. In Japan, where the demand for longer shelf life for fresh meat and other fresh food is on the rise, Kuraray can assist its customers to reduce food loss and waste with the environmentally friendly material, Plantic film. These market developments are expected to expand the bio-based barrier material business, with revenue of JPY 10 billion globally anticipated over the next 3 years.

Recycled Cup Maker MicroGreen Shuts Down

By Jim Johnson, Senior Staff Reporter, *Plastics News*

April 14, 2015 — An Arlington, Wash.-based cup maker, which used recycled PET and attracted millions and millions of outside investment, has "ceased operations."

MicroGreen Polymers Inc., only a year ago, indicated it was ramping up production of its cups from 400,000 to 2 million per day.

But now word comes that the maker of InCycle brand cups has closed its doors.

"We have ceased operation and are closed until further notice," according to a message on the company's voice mail.

InCycle cups were made from a minimum of 50 percent recycled PET, typically used soda and water bottles. Those bottles were grinded, melted and formed into sheets and then infused with micro-bubbles. The bubbles expand the volume of material and allows for the production of four cups for every plastic bottle that is recycled.

A voice mail message left with the company on April 14 was not immediately returned.
MicroGreen, when announcing its production increase last year, said its cups were big in the airline industry where they are used for hot beverage service. The company, at the time, said it was receiving investments from two different Native America tribes to fund the expansion.

A local story from *The Herald Business Journal* of Everett, Wash., indicated the company had raised more than $40 million from outside investors and had more than 100 workers at one time. The company dates back to 2002 and was co-founded by Krishna Nadella, who serves as CEO, according to MicroGreen's website. Former CEO Tom Malone served in that role from September 2006 until January, according to his Linkedin profile.

A story in *Plastics News* in January 2013 featured comments from company officials who saw a bright future and plenty of growth ahead for the company, which was operating just one thermoforming line at the time.

"Even if we only aim for the low-hanging fruit, we'll need 20 to 30 production lines," one company official said at the time. The company, at that time, had 45 employees with a goal of employing 200 to 300.

Faerch Plast Plans to Expand Global Footprint

By Packaging-Gateway.com

April 16, 2015 — Food packaging specialist Faerch Plast is planning to expand its operations to Australia, New Zealand, the US, Canada, South Africa, the Middle East and Israel. The company is building a network of overseas distributors, as well as investing in a team to support its growth beyond its EU home market.

As part of its expansion plans, the company will focus on the distribution of crystalline polyethylene terephthalate (CPET) containers for frozen and chilled convenience meals. CPET offers greater temperature tolerance from -40°F (-40°C) to 428°F (220°C) for freezer-to-oven or microwave convenience. These containers are claimed to be capable of eliminating negative effects on food flavour and aroma.

“We are looking forward to establishing and working with a network of highly reputable distributors to replicate this success across the rest of the world.”

Faerch Plast overseas markets sales director Joe Iannindardo said: “We have an unrivalled reputation as a market leader in CPET containers for the European frozen and chilled convenience food industry and we are looking forward to establishing and working with a network of highly reputable distributors to replicate this success across the rest of the world.”

Besides CPET containers, the company also plans to expand the availability of its dual-colour packs for enhanced on-shelf appeal and product differentiation and frost trays for shatter-resistance at low-temperatures.

Faerch Plast will debut containers produced from its MAPET II mono-material into the regions where it is not already present. The packs made from MAPET II are claimed to offer robust top sealing of fresh meat, poultry and fish. These packs offer the same properties as multi-layer materials but are more cost-effective, secure and environmentally friendly when compared to non-recyclable laminates.

Targeted at high-end convenience food products, Faerch Plast’s dual colour CPET trays feature one colour on the outside surface and another on the inside. Produced from a single substrate using rPET, MAPET II trays are available in a wide range of colours and transparent versions that offer clarity due to the absence of a hazy PE layer.

Thailand’s Royal Group Adding Thermoforming Plant in Indiana

By Jim Johnson, Senior Staff Reporter, *Plastics News*

April 17, 2015 — Royal Interpack North America Inc. is spending $12 million to make recycle-content PET clamshell containers in Anderson, Ind.

The new project will create up to 135 new jobs during the next three years, according to the company, which also operates an integrated PET bottle recycling plant, extrusion and thermoforming operation in Riverside, Calif.

“Indiana is a key strategic location in our expansion plans due to its proximity and logistical access to target markets,” said Visanu Chawla, CEO of Bangkok-based Royal Group, parent company to Royal Interpack North America, in a news release.

The new site in Indiana will serve as a hub for the company to serve customers in the Midwest, East Coast and Canada, the company said. RPNA is leasing and renovating a 40,000-square-foot facility and expects to produce 24 million pounds of clamshell containers annually.

The Indiana Economic Development Corp. is providing up to $675,000 in conditional tax credits based on job creation.

“RNPA may be one of Indiana’s first Thai businesses, but if trends continue, other companies from the region will be soon to follow,” Gov. Mike Pence said in a statement.

RPNA was founded in 2011. The company said it expects to begin operations in Indiana by late April. The company also operates a 200,000-square-foot facility in Chonburi, Thailand.



From the Editor

If you are an educator, student or advisor in a college or university with a plastics program, we want to hear from you! The SPE Thermoforming Division has a long and rich tradition of working with academic partners. From scholarships and grants to workforce development programs, the division seeks to promote a stronger bond between industry and academia.

Thermoforming Quarterly is proud to publish news and stories related to the science and business of thermoforming:

- New materials development
- New applications
- Innovative technologies
- Industry partnerships
- New or expanding laboratory facilities
- Endowments

We are also interested in hearing from our members and colleagues around the world. If your school or institution has an international partner, please invite them to submit relevant content. We publish press releases, student essays, photos and technical papers. If you would like to arrange an interview, please contact Conor Carlin, Editor, at cpcarlin@gmail.com or 617-771-3321.

Proposition 65 Actions that May Affect Plastics

By Devon Wm. Hill & Deborah C. Attwood, Keller & Heckman LLP, Washington DC

Over twenty-five years ago, California voters approved the ballot initiative known as Proposition 65 ("Prop 65"). Formally known as *The Safe Drinking Water and Toxic Enforcement Act of 1986*,[1] this law requires California to publish a list of chemicals "known to the State to cause cancer or reproductive toxicity." For chemicals that are listed under Prop 65, the law prohibits the knowing discharge or release into water or into or onto land where the substance will pass into a source of drinking water, and the knowing exposure of any individual to a significant amount of the substance without first providing a "clear and reasonable warning." It is the warning requirement that is relevant to the plastics supply chain, as it applies to potential consumer product, workplace, and environmental exposures. We focus here on the consumer product angle.

The intent of Proposition 65 was to establish a right-to-know law that would notify Californians regarding their potential exposure to listed chemicals. In practice, Proposition 65 is a chemical deselection initiative that encourages consumer abandonment of products that have a warning.[2] It is the responsibility of the manufacturer of the finished consumer product to determine whether its products can reasonably be expected to result in a significant exposure; fear of product deselection has resulted in downstream businesses often being more sensitive than individual consumers, and suppliers are often asked whether their products contain any chemicals listed under Prop 65. For upstream suppliers that sell intermediates for use in California, an evaluation of these products and the full range of their potential downstream uses is required to determine whether a warning under Proposition 65 would be required.

The statute contains an exemption from the requirement to warn if the potential exposure to a listed carcinogen "poses no significant risk" or to a listed reproductive toxicant will have "no observable effect." Notably, the statute does not define the key phrases "no significant risk" or "no observable effect." The implementing regulations, however, establish "safe harbor" levels in the form of "no significant risk levels" (NSRL) for carcinogens and "maximum allowable daily levels" (MADLs) for reproductive toxicants. When the use of a listed chemical will result in exposures below the safe harbor, no warning label is required. The Office of Environmental Health Hazard Assessment (OEHHA) within the California Environmental Protection Agency, which administers Prop 65, has established over 300 official safe harbor levels for listed substances. Even in the absence of a safe harbor level, companies can use risk assessment techniques to develop their own NSRL or MADL and determine whether the potential exposure from the intended use of the product would exceed those amounts, thereby requiring a warning. OEHHA also may issue Safe Use Determinations (SUDs) confirming that no warning is required for a particular application or category based on a showing that exposures from a specific use will not present a significant risk.

Two chemicals have faced significant Prop 65 activity: bisphenol A (BPA) and styrene. Because these substances are widely used in the manufacture of plastics—BPA in the manufacture of polycarbonate and epoxy resins, and styrene as a building block for other thermoformable polymers— we briefly describe their Prop 65 history.

BPA

OEHHA has (to date) twice unsuccessfully sought to list BPA under Proposition 65. The first attempt occurred in 2009, when OEHHA's Developmental and Reproductive Toxicant Identification Committee (DARTIC), which is an advisory panel that helps OEHHA determine whether a chemical is a reproductive toxicant, evaluated whether BPA had been "clearly shown through scientifically valid testing according to generally accepted principles to cause reproductive toxicity." In July 2009, the DARTIC voted against the listing, but left open the possibility for reconsideration if additional relevant data became available. The second attempt took place in 2013, when in January of that year OEHHA released a Notice of Intent to List (NOIL) BPA on Prop 65 as a reproductive toxicant (developmental endpoint), and concurrently proposed to set a MADL for exposures to BPA of 290 micrograms (μg) per day. Although OEHHA finalized the listing in April, 2013, a California court required the delisting of BPA pending resolution of still on-going litigation brought by the American Chemistry Council against OEHHA.

This February, OEHHA announced that the DARTIC will again be considering whether to list BPA on Prop 65. There has been a significant amount of new scientific data generated on BPA, including by the U.S. Food and Drug Administration (FDA). The DARTIC will evaluate the data and vote on the listing at its scheduled May 7, 2015 meeting. Although the current exposures to BPA have been repeatedly affirmed as safe by FDA, we consider it possible that BPA will be listed on Prop 65.

Styrene

OEHHA issued a NOIL for styrene in 2009, but the proposal was later withdrawn based on successful industry litigation in California state courts. In January 2013, OEHHA again proposed the listing of styrene on the basis of the 2011 the National Toxicology Program (NTP) listing of styrene in the 12th Report on Carcinogens (RoC) as a substance that is "reasonably anticipated to be a human carcinogen." This notice was withdrawn in March 2013, pending the results of federal litigation and additional peer review of the underlying studies.

In February 2015, OEHHA released a second NOIL for styrene, again referencing the NTP RoC. Industry is opposing the listing, and it remains to be seen whether the NTP RoC listing can serve as an adequate basis upon which OEHHA can list styrene.

Implications

Until either styrene or BPA is listed on Prop 65, manufacturers need do nothing but continue to monitor the regulatory status of these substances. If a listing does occur, however, we would expect manufacturers to receive many inquiries regarding whether BPA or styrene are present in their products and would require a warning or whether they comply with the safe harbor levels.

Products that require a warning may be considered for deselection by retailers and brand owners. Moreover, the importance of compliance with Prop 65 must be considered in light of how the law is generally enforced. Prop 65 is rather unusual in that it is not enforced by OEHHA, the relevant regulatory authority. Instead, public prosecutors, like the California Attorney General or county District Attorneys, can bring suit. If the prosecutor declines to enforce against an alleged violation, Prop 65 permits private citizens to initiate enforcement actions. Because 25% of any assessed penalty goes to a successful plaintiff, there is a substantial incentive to bring these suits. A number of public interest groups and law firms have systematically engaged in these so-called “bounty-hunter” suits, targeting industries that use a particular chemical in their products for alleged violations. These suits have become a significant nuisance for industry and often force companies into settlement simply to avoid the cost of litigation.

Changes to Prop 65

Having spent some time describing Prop 65, we would be remiss to not point out potential upcoming changes to the law. On January 12, 2015, OEHHA published a Notice of Proposed Rulemaking that would repeal and replace the current Prop 65 implementing regulations. The proposal would make significant changes to the regulations, such as what is considered a “clear and reasonable” warning, requiring certain chemicals to be named in the warning, and establishing a website where OEHHA would post information about products subject to Prop 65 warnings. The comment period for the proposal closes on April 8, 2015, and we would expect additional rounds of revision and comment for the proposed regulations. In the meantime, manufacturers should be aware of further activity regarding the potential listings of BPA and styrene, while tracking these potential major changes to the implementing regulations.

About the authors

Devon Wm. Hill is a partner in the Food and Drug practice group at Keller and Heckman LLP where he has worked since 1996. Mr. Hill represents clients and trade associations on compliance and testing issues surrounding the regulation of food, animal feed, cosmetics, and food and drug packaging materials in various jurisdictions around the world. Mr. Hill also advises on the burgeoning regulation of chemicals at the state level. Prior to attending law school, Mr. Hill obtained his Masters Degree in chemistry and worked as a university research chemist and in industry.

Deborah C. Attwood is an associate attorney in Keller and Heckman LLP’s Food and Drug practice group. She represents businesses and trade associations on global legal and regulatory compliance activities for human and pet food, animal feed, and food and drug packaging. Ms. Attwood assists clients with obtaining essential premarket regulatory approvals from governmental authorities worldwide and responding to regulatory enforcement actions and litigation. Ms. Attwood also collaborates with trade associations and companies to develop responsive strategies to new federal and state legislative and regulatory initiatives, particularly in the U.S., EU, China, and MERCOSUR.

Submission Guidelines

- We are a technical journal. We strive for objective, technical articles that help advance our readers’ understanding of thermoforming (process, tooling, machinery, ancillary services); in other words, no commercials.
- Article length:1,000 - 2,000 words. Look to past articles for guidance.
- Format: .doc or .docx

Artwork: hi-res images are encouraged (300 dpi) with appropriate credits.

Send all submissions to
Conor Carlin, Editor
cpcarlin@gmail.com

REDUCE! REUSE! RECYCLE!

Students "Race" to the Finish During NPE2015

By Lesley Kyle, OpenMindWorks, Inc.

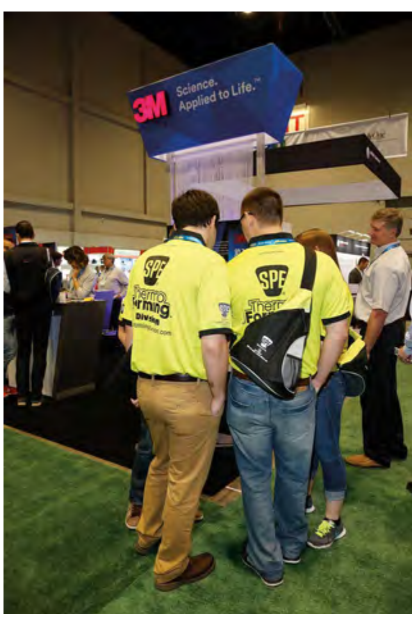
The Society of Plastics Engineers (SPE) launched its second outing of The Plastics Race® in Orlando on the second day of NPE2015. More than 80 university students from around the world participated in the event and formed teams of four. Armed with their smartphones and plastics knowledge, the students embarked on their journey to obtain questions and to find answers that were hidden throughout the show floor.

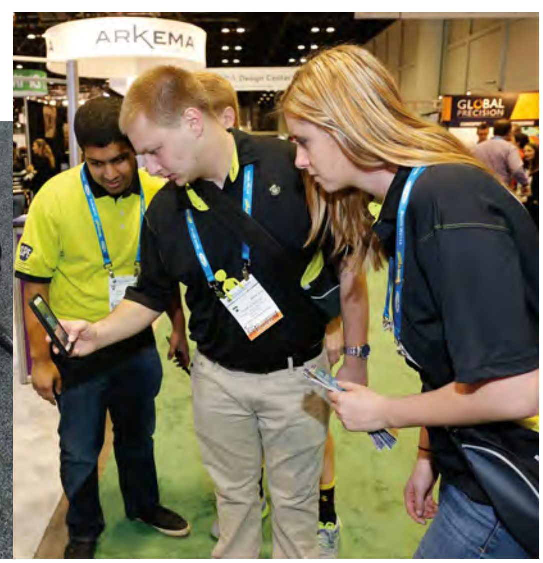
The enthusiastic and competitive teams rapidly fanned out across the massive Orange County Convention Center. Nearly 50 NPE exhibitors participated in the event by displaying QR code readers in their booths. The teams of students arrived at participating booths and quickly scanned the readers to receive a randomly selected plastics-related question. The SPE Thermoforming Division was one of several groups to contribute questions to this year's competition.

Teams earned points based on the difficulty of each question that they answered correctly. Five points were deducted if the team needed a hint to answer the question. Students could also add to their point tally by correctly answering a bonus question and by selecting one of several multiple- choice answers. The teams answered more than 50 plastics-related questions in ten categories during The Plastics Race. This back-and-forth dialog and engagement between students and the industry helped to pave the way for the next generation of plastics professionals.

Congratulations to the winners of The 2015 Plastics Race: Christopher Laverty and Dylan Clark of Ferris State University, and Stephen Bassler and Brady Taylor of Pennsylvania College of Technology! Their prizes consisted of gift cards to the Apple® Store totaling $6,000. Prizes were awarded to the second and third place winners as well.

The SPE Thermoforming Division sponsored the black and green shirts that the students wore during The Plastics Race. Eastman Chemical Company, ET Horn, the SPE Color and Appearance Division and the SPE Detroit Section also sponsored the event. Based on its great success at NPE, the Third Annual Plastics Race is planned for 2016 and will be held during SPE's ANTEC® Conference in Indianapolis, May 23-25.





The SPE Thermoforming Division sponsored the black and green shirts that the students wore during The Plastics Race.

SPE, Penn College of Technology, Paulson Training Form Alliance

March 23, 2015 — The Society of Plastics Engineers (SPE), the Plastics Innovation and Resource Center (PIRC) of Penn College of Technology, and Paulson Training Programs Inc. have entered into an alliance to offer plastics professionals and companies a resource for educational information, training programs, and certifications.

Drawing on its wide reach within the plastics industry, SPE will market this training and certification alliance within the community and will also initiate outreach programs to attract new members with their first year of premium membership as part of their training and certification packages. Paulson will provide discounts for existing SPE members who attend seminars through their Plastics Academy or onsite training. Penn College brings exclusive North American rights to the premiere Global Standards for Plastics Certification (GSPC) program. GSPC is the only recognized method of apprenticeship certification in the world for the plastics industry. It provides universal recognition of plastics worker's knowledge and capabilities, as well as demonstrated economic benefits to companies.

Those interested in learning more about how to get started, sign up for new membership, or sign up for individual or company training can contact SPE headquarters for details.

"As a combination of a robust industry association, a technical college and a world-class professional training company, this new alliance offers individuals and companies everything they need to know to make the most of their career and business opportunities in the plastics industry," said Russell Broome, managing director of SPE. "Existing and new members of SPE and the plastics community at large will benefit by having immediate access to the outstanding range of resources this new alliance brings".

The alliance partners have already identified the shortages of skilled worker and of new employees as critical industry challenges that they can help to address. Most plastics processors have ranked lack of enough skilled employees as their number one problem.

"Our alliance with Penn College and SPE is aimed squarely at these issues by providing technical training and by working to get the next generation of workers interested in plastics as a very lucrative and exciting career opportunity," said Craig Paulson, president of Paulson Training. "Our company, for example, has been giving seminars and marketing in-plant training solutions to the plastics industry for over 35 years."
Paulson will be supplying training in several formats including online, CD-based and seminars through the Paulson Plastics Academy and ProMolder Certification.

The academic and certification aspect of the alliance will be the specialization of Penn College of Technology, which, along with Paulson and SPE, will be offering GSPC certification to all plastics processors throughout North America. Hank White, director of Penn College PIRC is looking forward to working in this partnership to maximize the number of industry personnel who have a known global certification.

"The GSPC program is designed to give employers the ability to know that the people they are hiring have met certain standards in knowledge and skills," said Hank White, director of PIRC at Penn College of Technology. "On the employee side, having GSPC certification is a big plus on any resume."

Broome of SPE cited this example of how the alliance has already served as a resource for an industry company. "Soon after completing the alliance agreement, SPE received a call from a company in California looking for a training program for their injection molding business. SPE referred them to Paulson, and Paulson assisted the company immediately, offering the growing business a discount in SPE membership with a purchase of one of their products, and Penn College supplied research information and details about the GSPC certification program."

The alignment of the three entities couldn't have come at a more opportune time, according to Broome. "The economy is showing promising growth, especially in the domestic manufacturing sectors, causing more and more companies looking to obtain key industry information and to find qualified skilled people."

Student Programs

Free Student Memberships from SPI/SPE

There was a groundbreaking announcement made at the 2015 NPE/ANTEC event by Bill Carteaux, President of SPI and Wim DeVos, CEO of SPE: students will now have SPE membership underwritten 100% by both SPI and SPE! According to *Plastics News*, SPI will cover a portion of the dues for student members of SPE and package their SPE membership with an SPI electronic membership that plugs plastics students and future industry leaders into the biggest industry trade associations, right at the start of their careers. Student membership dues will be waived and SPI and SPE will share the membership cost for each student taking advantage of this offer. *Note: This is a promotional program only open to US citizens currently residing in the United States.*

Twin-Sheet Mold Needed – Can You Help?

Chris Gagliano at Penn College of Technology is trying to help a 3rd year student to use twin sheet forming as the basis of her Senior Capstone project this coming fall semester. Chris will be providing guidance through all facets of the project. One of the major hurdles to overcome is securing a tooling donation (obsolete tools gladly accepted) that will work with their MAAC single-station former. The maximum mold size is 36" x 48" with a maximum shut height of 25". The goal is to have the tooling available by this coming June with enough time to make necessary mounting revisions before the project begins in mid-August. Please advise Chris at cjg6@pct.edu if you can help.

Thermoforming Scholarship Winners — Where Are They Now?

Anna Macherkevich - 2014

Bill Benjamin Memorial Scholarship

"I finished my undergrad degree on March 28, 2015. Graduation criteria included finishing all classes in the ME curriculum as well as thesis completion… My thesis was a DFSS project on controlling the gloss levels of interior hard-trim parts made out of unfilled Polypro. …I have accepted a full-time offer at Fiat Chrysler Automobiles in the Chrysler Institute of Engineering (CIE) program. In this program I will rotate through 8 engineering departments and earn my Master of Science degree in Mechanical Engineering." |

Right: Kettering students investigate an extruder. Below: Students observe and learn about the oven used in thermoforming.

Using Logic Models to Predict Efficacy in Industry-University Partnerships

How Kettering University is Making a Difference in Workforce Development

By Eve A. Vitale, Director of Philanthropy - Corporate & Foundation Giving, Kettering University

Part 1 of a 2-part series

Author's Note & Introduction

In 2012 Kettering University decided it wanted to explore ways to increase student interest in the plastics industry. The University planned to use its Industrial and Manufacturing Department curriculum and an upgrade to its Polymer Processing Laboratory to engage students. In late 2013, after initial measures were taken, a logic model was developed to predict the impact of ongoing efforts to strengthen workforce development for the plastics industry. This two-part paper will discuss Kettering's success. The continuing growth of student interest in, and engagement with, thermoforming technology is critical to the long-term health of your industry. It is truly heartening to witness the accomplishments of strategic and collaborative effort. What may be of particular interest to the readers of *Thermoforming Quarterly* is the way in which the donated MAAC thermoformer is being utilized by Kettering's SPE section and the Plastics Engineering Club.

The Kettering Industrial & Manufacturing Engineering Program

Mark Richardson, Lecturer in the Department of Industrial and Manufacturing Engineering at Kettering University, is working hard to recruit chemical, mechanical and industrial engineering students to coursework in polymers, mold design, and plastics processing. In addition, he ensures that these engineers look at design for sustainability and recyclability.

The Polymer Processing Laboratory will be used to support a new course – *CHME491 – Plastics Engineering* in the fall of 2015. This course will be funded through the American Chemistry Council's Automotive Plastics Division. Kettering proposed that the culmination of the course include over 20 hours of lab time for students to develop a thermoformed project. This gives the ACC something tangible to show as impact of their support. We see thermoforming as a way to get students excited about the plastics industry.

The Kettering SPE Student section and Plastics Engineering Club are currently working on multiple thermoforming projects. Mr. Richardson is working with industry partners on thermoforming part development. A donation from the Ford Motor Company of a GEISS T8 vacuum former will allow for more complicated project development and create further thermoforming learning opportunities for undergraduate and graduate students.

Project Examples

One student project focuses on recycling and utilizes our MAAC thermoformer, purchased with grants from MAAC, the SPE Thermoforming Division and the Dart Foundation in 2013. The president of the Plastics Engineering Club, Chris Lafayette, developed two thermoforming subgroups within our Plastics Engineering Club: the *Thermoforming Recycling to Re-Use* student SPE teams. These two teams are the Plate Team and the Cup Team. The teams are part of the broader campus recycling program. Students collect water bottles, grind them, pelletize them and will soon use the recycled PET to manufacture sheet and thermoform it into plates and cups that the club will use for lunchtime meetings. In addition to learning about plastics recycling, this project has been instrumental in getting our students interested in thermoforming. The plate and cup teams are working on mold design, mold fabrication and will begin manufacturing cups and plates when they return from their co-op work terms in July. As they thermoform different formulations of recycled and virgin resin for their projects, we would like testing to become part of the process. Students will learn to use the Goettfert Capillary Rheometer, the Charpy Izod Impact Tester, and the hoped-for UTS tensile test machine. Specifically, they will cut or stamp out tensile test bars from the manufactured sheet. These bars will be used to test strand orientation and localized strength of the sheet as well as provide DOE data relating to thermoformability.

Corporate Programs

Our other section of SPE students is beginning a project for a corporate partner this term. The company uses a basin for strand

and epoxy to support carbon fiber lay-ups. They are in need of plastic liners to ease the clean up process, but the basin is oddly shaped. We have CAD data for the basin and we are developing a mold prototype. We plan to be in production on the MAAC thermoformer by the end of the term, most likely using HDPE.

Kettering is working with Vantage Plastics to get a mold that would fit the MAAC thermoformer so our students can run trials of paint-filled HDPE. The HDPE was given as a donation from Chevron Phillips. The mold from Vantage will be used to form test parts in the development of reusable dunnage for the automotive industry, specifically for GM and FCAGroup (Chrysler).

The Academic Program & Polymer Processing and Testing Laboratory

Kettering has 11 week terms and the pace is rapid. Many upper-level students take 20-24 credits. To fully engage these students in project work on such a short time frame, we either utilize multiple ongoing terms (as with our Thermoforming Recycling to Re-Use student SPE Teams) or we utilize a process with a quick turnaround and inexpensive materials. For thermoforming, we are able to prototype molds in wood and in some cases move on to machined aluminum fairly inexpensively for use in our MAAC thermoformer. We believe that thermoforming is the process of choice for projects which are time-limited.

The Polymer Processing and Testing Laboratory is available to undergraduate and graduate students, as well as industry partners, and offers the following benefits:

- It will be used to collect data from various plastics processes including thermoforming. This data will be used in combination with our advanced quality courses for statistical process control and DOE.
- Availability to every mechanical, electrical and industrial freshmen engineering student as part of the required coursework - *Manufacturing Processes* (IME 100).
- Open to all self-selecting upperclassmen who are working toward specific coursework in plastics processing (*IME Plastics Processing I & II*)
- Availability to students in their senior year who are doing independent studies in plastics processing, design, and development or doing a capstone class.
- Open to industry partners who require research assistance from academia.
- Open to graduate students working toward a Master's of Science in Engineering with a concentration in Manufacturing.
- Assists in the development of a pipeline of manufacturing talent (addressing the skills gap of engineers and technicians), thus making it possible for American manufacturers to fill current and long-term vacancies.
- Facilitates cooperation between faculty and industry to bring about transformative innovation to plastics processing while encouraging sponsored research.
- Draws on the strengths of the University's nationally-recognized faculty as well as research and technical staff.

The Co-Op Program

Kettering University's 91-year history of offering co-operative education programs makes it a leader in engineering undergraduate experiential education. The ultimate goals of the Kettering Professional Cooperative Education Program are as follows:

- To develop a strong and positive correlation between a student's academic program at Kettering and the educational experience with his or her employer.
- To provide educational experiences that orient and integrate the student into a productive professional role at the employer organization.
- To develop positive work-related habits and characteristics in students.

Kettering's Co-op Program is intended to help its students achieve their educational and career goals while meeting the ever-growing workforce needs of its co-op employers. Students can begin work as soon as July after high school graduation and continue on a quarterly rotation until graduation. To graduate, each student is required to work for at least five terms, but many students work up to two and a half years in relevant engineering positions. Kettering University's program is designed to create a pipeline of well-trained and motivated engineering graduates to meet co-op employers' full-time workforce needs.

Firing Up the Program

Kettering's focus on undergraduate engineering education and co-operative work experience sets the stage for strong industry partnerships. It is my theory that there is a logical rationale for strengthening these partnerships to increase favorable outcomes for both industry and academia. Utilizing the W.K. Kellogg Foundation's *Logic Model Development Guide* made the connections easy to see and will also make it easier to track outcomes for assessment purposes (*Model Development Guide, 2004*).

In 2012 Kettering University hired an Industrial & Manufacturing Engineering faculty lecturer, Mark Richardson, to teach *Introduction to Manufacturing Processes* to all incoming engineering students. When he noticed several plastics processing machines in the lab weren't being utilized, he made it his goal to "engage students in plastics to help fulfill industry workforce needs." Upon investigation, the barriers to his plan

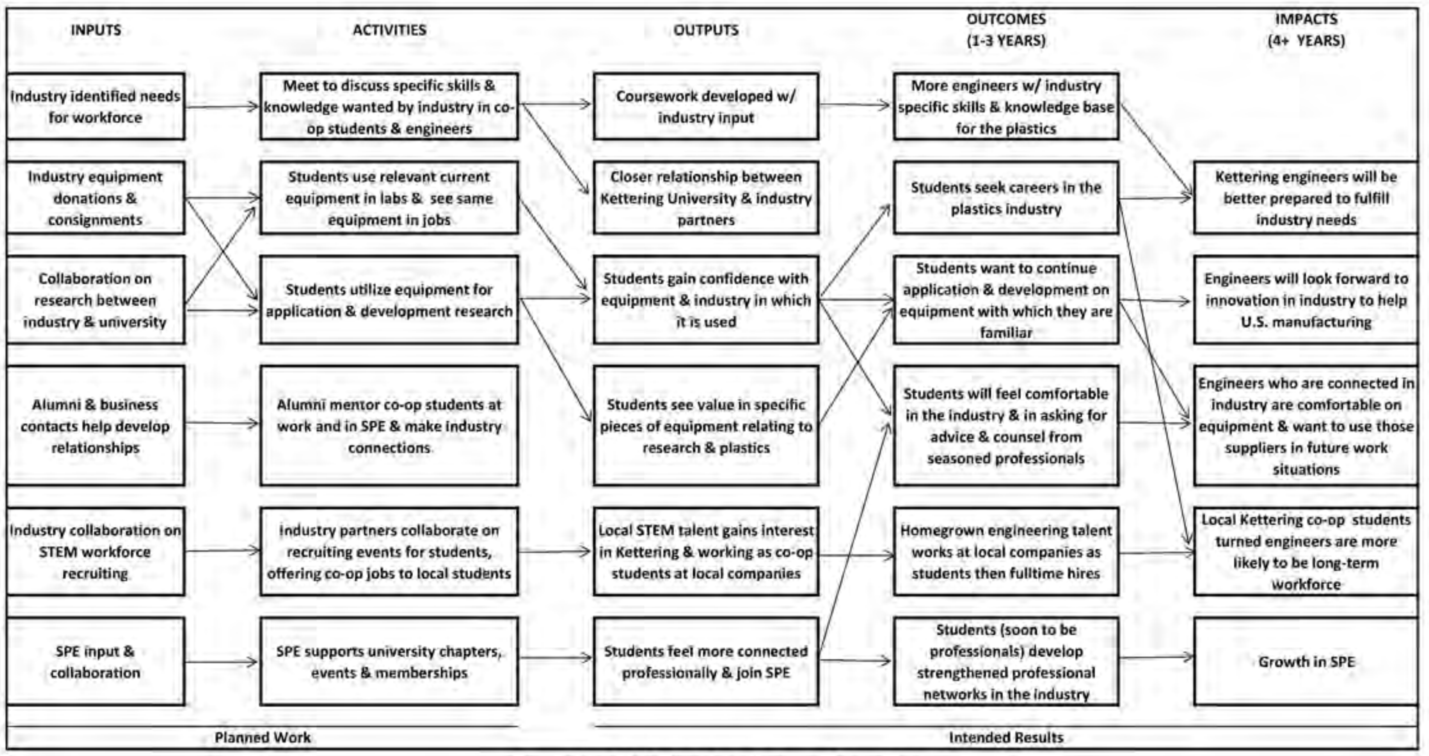


Figure 1: Logic Model for Industry/University Partnerships

were uncovered: old equipment, no lab funding for materials, lack of current industry relationships, lack of understanding between academia and the plastics industry, and lack of strong collaboration with SPE and SPI.

The first thing Mark did was schedule a trip to Orlando for the 2012 NPE show. He then reached out to Kettering alumnus Dan Joseph, President and CEO of D.R. Joseph, Inc. Dan is known for has expertise in internal bubble cooling control systems and technologies. Dan put Mark in touch with Bill Carteaux, President and CEO of SPI. After a very successful trip to Orlando and a subsequent presentation to SPI's Equipment Council, many relationships were cultivated. These and other relationships are the key to the momentum and success Richardson is now experiencing in developing student interest in plastics at Kettering University.

Logic Models & Relevance to Workforce Development Efforts

Looking at *Figure 1: Logic Model for Industry/University Partnerships* you can see how relationships fuel the engine that is driving the ever-increasing need for workforce development in the plastics industry. It is my hope that a snapshot of the Kettering University success will prompt more companies with workforce challenges to get involved with Kettering or a university of their choice.

A logic model works like any other model with inputs and outputs. The illustration on the following page provides a visual representation of how we implemented our logic model at Kettering. The inputs needed to create impactful change include:

- conversations between industry and academia regarding workforce needs
- alumni and business relationships
- help in recruiting talented local high school students to pursue engineering careers
- collaboration on research
- SPE collaboration and equipment donations or consignment

(Part 2 of this article will appear in TQ3 and will discuss the practical application of the logic model framework to Kettering's program.)

Thermoforming Technical Problems I Wish I Could Solve

Stretching Multilayer Sheet

By Jim Throne, Dunedin, FL

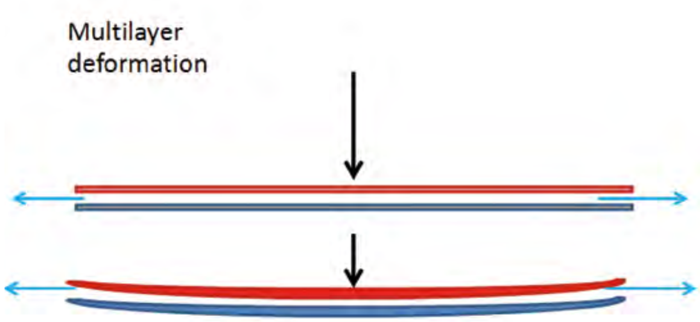
Prologue

If you read last quarter's installment on heating multilayer sheet, you should've asked the question: what about stretching the stuff? [If you didn't, shame on you! Dig out that old copy – or find the electronic version in your inbox – and read up! I'll wait.]

Now, you know that I've discussed the challenging and as yet unsolved technical aspects of heating multilayer sheet. Of course, we are well aware that multilayer sheet is heated and stretched into functional products on a daily and hourly basis. So why am I concerned about stretching multilayer sheet? A couple of reasons come to mind: delamination and pin-holing. Let me explain.

How does multilayer sheet stretch?

First, we need to assume that all the layers have reached their forming temperatures. The thicker the sheet, the more important this aspect becomes. But when and how that occurs is a topic for another time. We stretch a heated formable sheet by applying differential pressure across it. The sheet resistance to stretching is its modulus, or in this case, its composite modulus.



The stiffness of a beam is given as:

$$S=E(T)l$$

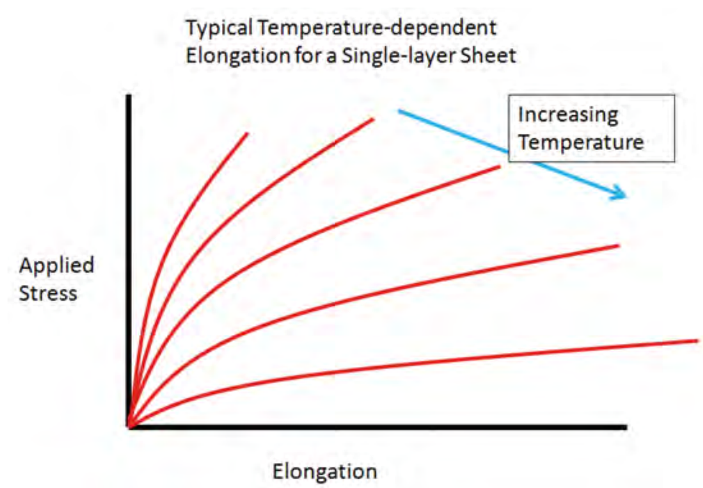
Where E(T) is the temperature-dependent modulus and I is the moment of inertia, defined as $I=bh^3/12$. An effective modulus for a given layer "i" can be defined as:

$$E_{ff,i} = E_i(T)\left(\frac{h_i}{h_{total}}\right)^3$$

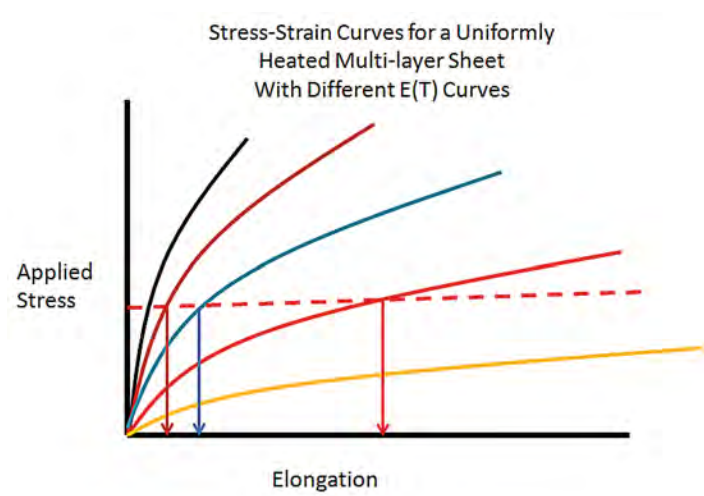
Where h_{total} is the total sheet thickness. The effective modulus for the entire multilayer structure can be written as:

$$E_{ff} = \sum E_i(T)\left(\frac{h_i}{h_{total}}\right)^3$$

By now everybody should be familiar with the typical temperature-dependent stress-strain curve for a plastic:



We can use this same figure to demonstrate the stretching issue with multilayer sheet:

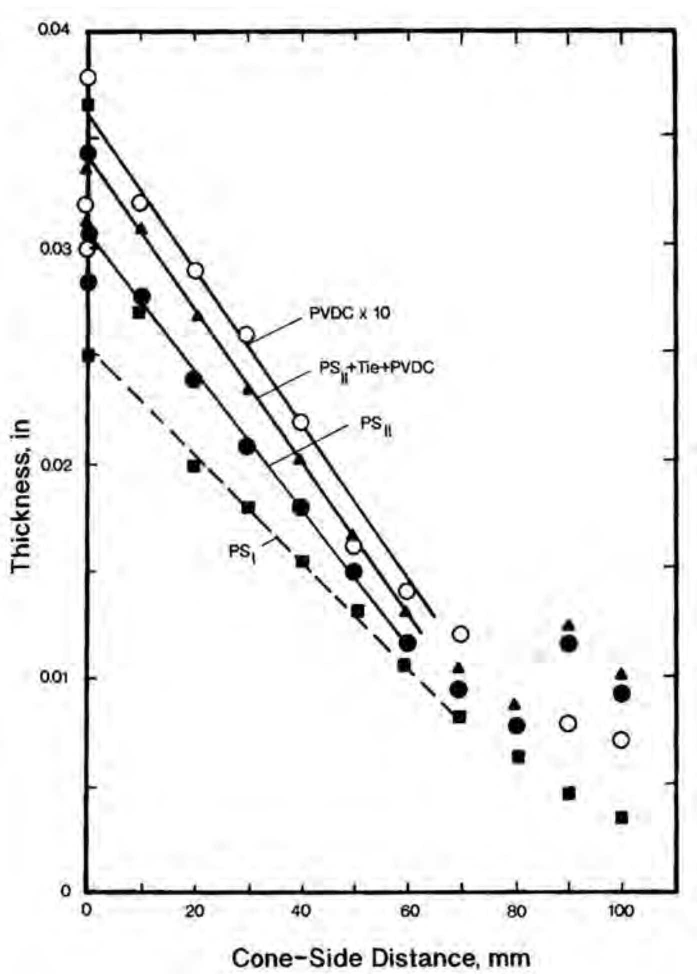


Now the stress-strain curves are for different plastics at one temperature. If the plastic depicted by the yellow (far right) curve was by itself, it would be easily thermoformed into a useful part at this temperature. On the other hand, the plastic depicted by the black (far left) curve is far too stiff. We would need to substantially increase its temperature before it could be formed successfully.

So we can conclude that, as is often the case, *the thickest layer with the highest modulus at the sheet temperature will offer the greatest resistance to bending*. But more importantly, consider this: even if our black plastic is very thin and our yellow plastic is very thick, and even if the yellow plastic is well into its normal forming temperature, attempting to bend or stretch the black plastic can lead to splitting or separation from abutting softer layers. On the other hand, if we heat our black plastic to its normal forming temperature, the yellow plastic may be so hot that it may pinhole or degrade.

I still don't know how multilayer sheet stretches!

Okay, let's assume that every layer is heated to its forming temperature range. Consider the forming of this PS+tie+PVC multilayer:



Why is this? Regardless of the difficulty of the draw, the interfacial adhesion of the layers is far greater than any interfacial shear forces. It turns out that each layer is locally stretched in proportion to every other layer. Here's how you can verify this. Lay several sheets of the same plastic one atop another without any 'glue' between them. Heat them, form them, peel them apart, and measure their individual local thicknesses.

So, we know everything, right?

Not quite. Whenever a designer is considering creating a multilayer product, he/she must be aware of the temperature-dependency of each of the layers. I am unaware of any database of temperature-dependent moduli for most of the plastics used in multilayer structures. And we really haven't addressed another problem, particular to thick-gauge sheet – compression buckling and delamination that can occur when sheet is concavely drawn. We'll save that for later.

On the Potential of Stereo Digital Image Correlation in Thermoforming

By Bart Van Mieghem, Martijn Hamblok and Albert Van Bael, KU Leuven, Technology Campus Diepenbeek, Diepenbeek, Belgium; Bart Buffel, Marijke Amerijckx and Frederik Desplentere, KU Leuven, Technology Campus Ostend, Ostend, Belgium; Jan Ivens, KU Leuven, Technology Campus De Nayer Sint-Katelijne-Waver, Sint-Katelijne-Waver, Belgium

Abstract

Process insight in thermoforming is a critical factor to secure the production of high quality parts. In thin gauge thermoforming, different tools exist to monitor this complex process and to gain insight. In heavy gauge thermoforming, this is not yet the case. The current paper demonstrates by means of three applications how in situ digital image correlation (DIC) can be used as a tool to acquire in depth knowledge of the ongoing process. In the first application, it is used as a 3D reconstruction tool. The second describes how full fields wall thickness distribution can be retrieved. The third application combines the previous two and demonstrates how the effects of asymmetric heating can be quantified. The technique makes it possible to visualize in a simple and straightforward way the amount of thinning of the sheet in every step of the process. In all three cases, the main goal is to provide more process insight, making it easier for the thermoformer to master his process, reduce the setup time for new products and control the process parameters.

Introduction and Motivation

Thermoforming is a complex process with many factors influencing the product quality. The latter is primarily defined as the material thickness distribution. In the last two decades major improvements have been realized with regard to the reliability, energy efficiency, automation and accuracy of the equipment, but in industrial practice the thermoforming process unfortunately remains primarily an experience and trial and error based technology. This is in particular the case for heavy gauge thermoforming due to the relatively smaller batch sizes and more frequent product changes than thin gauge thermoforming. The trial and error approach is related to a limited degree of process insight and use of thermoforming simulation tools. This leads to suboptimal processes and long optimization procedures requiring skilled and experienced people.

In thin gauge thermoforming, process insight has proven to be highly important to evaluate the effect of process parameter settings on the final product quality.

Martin et al. [1] recently published details of a prototype multivariable instrumentation system for use in thermoforming and highlighted its added value. A similar commercial instrument called ToolVu was recently developed by uVu Technologies [2]. In heavy gauge thermoforming on the other hand, little to no effort has been reported to obtain more in-process data. By heavy gauge thermoforming we do not strictly refer to the thickness of the sheet ($\geq$ 1 mm), but more to a class of processes that involve big products, most of the time formed by simple vacuum forming or free forming and which are cut-sheet fed. These thermoforming process variants have the advantage that the sheet is visible during every step of the process: heating, sheet transfer (or heater retraction depending on the type of machine), bubble inflation for positive products, forming, cooling and demolding.

In order to respond to this lack of process insight, a technique called in situ stereo dimensional Digital Image Correlation (DIC) [3], which is an optical non-contact full field surface deformation measurement method, is used. Different strategies are presented for the use of DIC in order to get improved process insight, offering perspectives for easier process optimization and minimum setup times. Whereas DIC is widely used for other applications where full field strain measurements are required [4], applications for thermoforming are limited. Besides our own publications on that topic [5-7], only one related work is known to the authors [8]. In the latter study the full potential of in situ measurements is not addressed since only the full field strain field at the end of the thermoforming process is evaluated.

As the paper is meant to be a compilation of different applications of DIC, the material and methods section is written in a generic way containing a brief explanation on the implementation of DIC in thermoforming. The subsequent paragraphs elaborate on three cases were DIC is used in different ways to assist the thermoformer to gain more insight in the forming process.

Materials and Methods

Stereo Digital Image Correlation Setup

DIC enables a sub-pixel measurement accuracy of displacements and strains on the surface of complex parts. To perform stable and repetitive DIC measurements during the thermoforming process, 2 AVT Stingray F-201 cameras with high resolution, low distortion lenses are mounted steadily on top of the thermoforming machine. The distance to the target depends on the desired field of view (FOV) and depth of field (DOF). The FOV for rectilinear symmetric lenses can easily be calculated when the focal length (f) of the lens and the size of the sensor (d (width or height)) are known. From these, the angle of view (*a*) can be calculated using Equation 1 [9].

$$\alpha = 2arctan(\frac{d}{2f}) \qquad (1)$$

The field of view in either width or length can then be calculated as function of the distance to the target (L) with Equation 2:

$$FOV = 2tan(\frac{\alpha}{2})L \quad (2)$$

Combining Equation 1 and 2 leads to following simple expression for the field of view in either width or height direction:

$$FOV = \frac{d}{f}L \quad (3)$$

The depth of field (represented in Figure 1) is defined as the range of distances in which objects are imaged with acceptable sharpness [10]. In photography, DOF is mostly calculated based on the Circle of Confusion (CoC) and can be expressed mathematically [11].

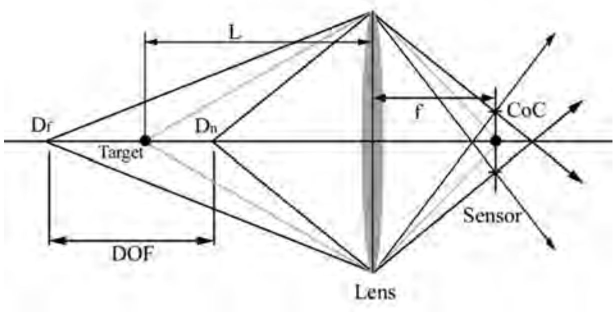


FIGURE 1: *Schematic representation of the depth of field (DOF) and circle of confusion (CoC); far distance (Df) and near distance (Dn) of acceptable sharpness.*

The thus obtained DOF results are strongly dependent on the chosen CoC, which in turn depends on the visual acuity of the person who is judging the picture, the viewing conditions and possible enlargements [12]. Since the pictures used for DIC measurements are not judged on sharpness by people, but are only depending on grey value differences within a subset of pixels and since a little blur is favorable for stable interpolation [13], the mathematical calculations of the DOF are only an approximation of the DOF that DIC algorithms can handle. The method to define the real DOF without compromising the measurement accuracy will be discussed in a future publication.

Since stereo DIC requires two cameras, the inter-camera angle is also of importance. Sutton et al. [3] recommend a stereo angle between 10° and 30° to have good sensitivity to out-of-plane motion while maintaining modest perspective differences between corresponding image subsets. However, if large stand-off distances are required and out-of-plane sensitivity is of importance, as is the case in thermoforming, angles of 60° or higher can be employed at the expense of in-plane accuracy. For all three cases in the next paragraphs, the chosen angle is kept between 25° and 37°.

DIC requires a random, non-repetitive, isotropic and high contrast pattern on the sheet in order to ensure discrimination between the imaged pixels. Besides this, when using it in thermoforming applications, some extra criteria come into play. The paint should be temperature resistant, it should withstand high strain without cracking, bond well with the thermoplastic, be non-toxic, cheap, fast and easy to apply. For research purposes, a spray paint F122304 WB Elastic ACRYLIC from Flanders Plastic Color satisfies all these needs. For industrial purposes, an easier way to apply the pattern is to print it. An example of ink that meets the abovementioned requirements and which is commercially available is the VUTEk GS-TF ink from EFI [14]. The recently developed UV curable ink Uvijet KV from Fujifilm also promises to be applicable claiming strains over 500% without cracking [15].

Besides the camera setup (including calibration and synchronization) and the speckle pattern, care needs to be taken to have uniform lighting. Also, the camera shutter speed must be high enough to avoid motion blur. Subsequently a noise evaluation is carried out meaning that the averaged standard deviation between the region of interest of a reference picture and several still, unloaded, pictures is calculated. This technique is referred to as a self-correlation test. The result is an estimate of the camera noise. This noise impacts the measurement accuracy and should be kept as low as possible. An interesting paper concerning this issue is published by Wang et al. [16]. The particular average values in our cases range between 0.5 and 1% depending on the setup.

The DIC software used is the 3D module of MatchID, a software developed at the KU Leuven Technology Campus Ghent [17]. The correlation settings for the displacement calculations are in all cases: a zero-normalized sum of squared differences algorithm (ZNSSD), a bicubic polynomial interpolation, an affine transformation both in 2D and stereo, a spatial correlation with updated reference and Gaussian noise handling. As to the strain calculation algorithm, either the Green- Lagrange or the logarithmic Euler Almansi strain tensor is used, combined with a bilinear quadrilateral interpolation.

The DIC software calculates full field 3-dimensional displacements of the sheet surface. From these displacements, surface strains are calculated and when assuming volume conservation, the wall thickness can be obtained [5]. This approach is schematized in Figure 2, and will be adopted in cases 2 and 3 discussed further on.

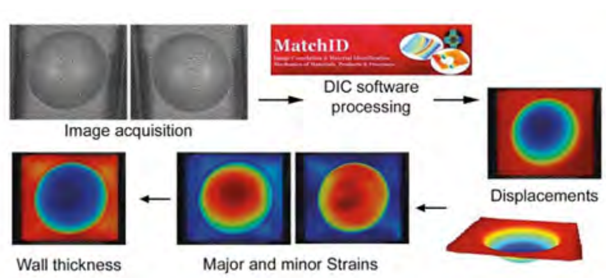


FIGURE 2: *Digital image correlation applied to the thermoforming process.*

Sheet Material and Machine

The material used in all following cases is a thermoforming grade of high impact polystyrene (HIPS) with a thickness of 1 mm (+/- 0.02 mm). The methodology can also be applied to other thermoplastics, provided the assumption of volume conservation of polymeric materials is valid.

Sheet Material and Machine

The material used in all following cases is a thermoforming grade of high impact polystyrene (HIPS) with a thickness of 1 mm (+/- 0.02 mm). The methodology can also be applied to other thermoplastics, provided the assumption of volume conservation of polymeric materials is valid.

The thermoforming tests have all been performed on an Illig UA200ED industrial hydraulic thermoforming machine capable of forming sheets up to 2000 x 1000 mm and a thickness up to 10 mm. The machine is equipped with ceramic infrared heating elements installed in dual (upper and lower) heater banks. In cases where measurements are performed during the heating stage, only the lower heater bank is used since the upper heater would obstruct the view of the cameras. The temperature setting of the heaters is controlled by thermocouples in three of the centrally located heating elements (control elements), all other elements are individually switched on and off (PID controlled) according to the temperature of the control element to which it is assigned. Although this is a rather outdated way of controlling the temperature and newer systems allow for individual temperature or power setting of the elements, it is still widely used in industry.

The sheet temperature is separately measured with an infrared temperature sensor (Fluke 576) at a rate of 10 Hz, with a spot size of 23 mm, a distance from the sheet of 500 mm and an accuracy of ±0.75% of the reading in °C. The sensor emissivity is set to 0.96, i.e. the average value obtained from a comparative study between thermocouple and infrared measurements of a material with a known emissivity and the high impact polystyrene. In order to assess the impact of the through thickness temperature gradient, especially when heating from one side, a Matlab® script based on the finite differences method is developed. With this tool it is possible to simulate the different heating steps such as convective preheating in a hot air oven, convective cooling due to transport from preheating station to forming station, radiative heating and a pre-forming holding phase, also called the transfer phase. The boundary conditions include thermal material properties, radiative heating power, heat transfer coefficients and convective heat loss to the environment. Penetration depth of the IR radiation and wavelength dependent heat absorption by the material are currently being implemented in the code. In the case of a HIPS sheet with 1 mm thickness, preheating is not necessary and only the radiative heating and the pre-forming holding phase are simulated. When assuming constant material parameters (density: 1050 kg/m³, specific heat capacity: 1200 J/kgK, thermal conductivity: 0.17 W/mK) and convection losses at the sheet surfaces (16 W/m²K, defined following the procedure described in [18]), a maximal gradient of 10°C between top and bottom of the sheet at the end of the heating stage (51 s, 150°C, based on the IR measurements of the top surface) is calculated. After the retraction of the heaters (transfer phase), which takes 3.7 seconds, the maximal gradient within the 1 mm sheet drops below 2.5°C (Figure 3) and can be neglected.

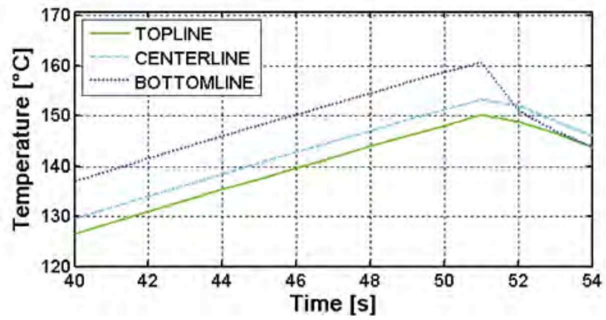


FIGURE 3: *Matlab® plot of the calculated top, bottom and core temperature at the end of the heating step and during the pre-forming holding stage as a function of time for a 1 mm HIPS sheet heated with bottom heater uniformly set to 300°C.*

Results and Discussion

In this section, a concise overview of three different applications of DIC is presented. The first two have been discussed in more detail in previous publications [5, 7], whereas the third is a novel application that combines aspects of the first two cases.

An overview of important parameter settings for the different cases is summarized in Table 1.

	CASE 1	CASE 2	CASE 3
Camera stereo angle [°]	37	30	25
Distance to target [mm]	2000	1100	1200
Lens focal length [mm]	25	25	8
Mold shape	Washing sink	Partial hemisphere	Suitcase shell
Mold dimensions [mm]	540 x 400 x 130	250 x 250 x 65	630 x 445 x 160
Mold material	AISI 304 0.8 mm SPIF	Aluminum 2 mm SPIF	Aluminum machined
Heating	Single sided (300°C)	Dual heater (250°C)	Single sided (300°C)
Subset size [px]	40	29	21
Step size [px]	10	10	3
Strain window [px]	10	15	5

TABLE 1: *Overview of important settings for each case*

The word "SPIF" in Table 1 stands for single point incremental forming. More details on this forming process for sheet materials can be found in [19]. It is well suited for producing molds intended for low pressure forming techniques of polymers and composites [20].

CASE 1: DIC for 3D Shape Evolution

The intent of this setup is to check whether molds based on thin sheet metal could be used for low pressure forming processes such as vacuum forming. The formed product, i.e. a washing sink, looked good at first sight, but after laser scanning the final product and comparing this scan to a laser scan of the mold, it was clear that the lower part (just behind the drain of the washing sink) was not completely formed. Deviations between sheet and mold reached up to 6.4 mm which is unacceptable. Since DIC measurements were performed during the forming process, the reason for this incomplete forming was quickly revealed by taking a closer look at the history of a cross section in the length direction (Y-axis) of the washing sink (Figure 4). The reference cross section (REF) is compared to the first picture after heating (STOP_HEATING) and to other incremental steps in the forming process. During heating the sheet sags symmetrically under its own weight until the start of the molding, but when the vacuum starts (line 80 and further), the sheet forms asymmetrically with a preference for the front part of the mold. This part closely follows the actual mold surface. At a certain moment, the sheet closes the vacuum holes situated in the drain of the washing sink before it is able to completely take the shape of the back side of the mold. This results in an incompletely formed part that in this case is hard to distinguish of the final part without subsequent geometric measurements. By using DIC, the reason for the problem could be revealed and the resulting insight led to successful modifications of the position of the vacuum holes giving good final products, perfectly copying the mold.

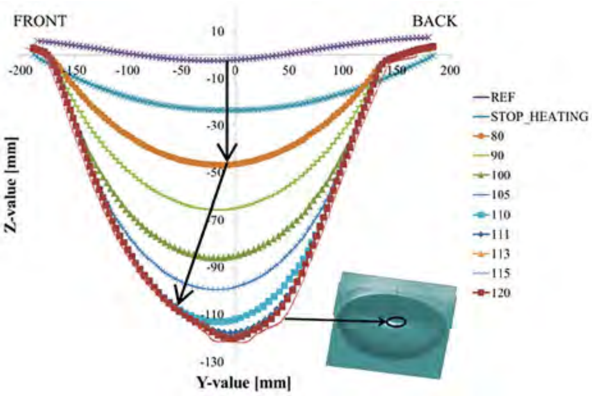


FIGURE 4: *Shape of a central cross section during heating and forming. Numbers in legend represent picture numbers [18].*

CASE 2: DIC for Full Field Wall Thickness Evolution
In a standard process startup or process optimization, products are formed with different initial parameters and each time the thickness of the final product is evaluated by discrete tactile measurements in a partial cross section of the product. This measuring technique is slow, operator dependent and only gives data in specific points on the final product, resulting in mostly

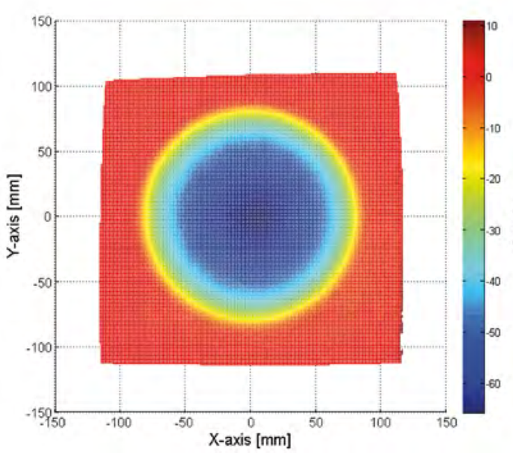


FIGURE 5: *Top-view of the partial hemisphere, color scale representing the 3rd dimension showing a quasi-perfect shape symmetry.*

complicated judgments on the causes of the thinning of the polymer sheet. Since DIC is able to follow displacements and deformations of speckle patterns on the sheet surface, the wall thickness over the entire surface can be mapped in each step of the process. In this way, the systematic use of DIC makes it easier to establish causal relations between the thermoforming parameters and the final thickness distribution of the product.

Figure 5 represents the top-view of the three-dimensional reconstructed shape of the partial hemisphere. From this figure, which looks perfectly symmetric, meaning that the mold is adequately copied, one would also expect a symmetric thickness distribution. Simulating this simple academic shape with thermoforming finite element software would also predict a symmetric thickness distribution. It is even the case that a typical axisymmetric product would only be modeled for one quarter to limit the required computational time. When looking at Figure 6 though, representing the full field final thickness distribution making use of the methodology illustrated in Figure 2, one can clearly identify an asymmetry.

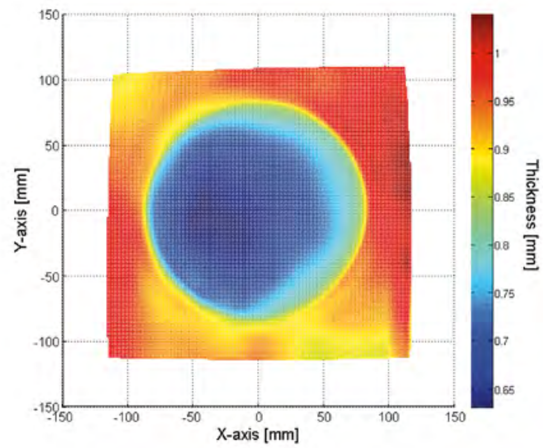


FIGURE 6: *Top-view of the partial hemisphere, color scale representing the thickness distribution, showing a clear asymmetry.*

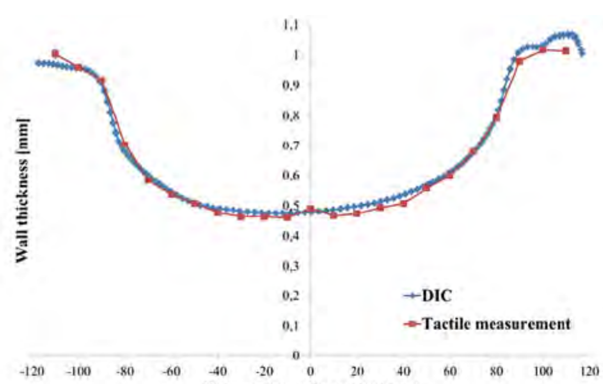


FIGURE 7: *Comparison of thickness measuring principles (DIC and tactile measurement) in a cross section of the partial hemisphere.*

To make sure that no false conclusions are drawn from this DIC approach, a discrete number of thicknesses are measured along a central cross section parallel to the X-axis with a Mitutoyo


Low Flex
Thermoformer


Linear Rail
Trim Press

209-573 dial caliper gage with a resolution of 0.01 mm and an accuracy of 0.02 mm (Figure 7). From these measurements we can conclude that the DIC measurement corresponds well to the manual measurement, confirming that the thickness distribution is not symmetric although the global shape of the partial hemisphere is symmetric. The reason for this is mainly the prior sheet extrusion process inducing thermal stresses in the material. More details can be found in [5]. Again, in this second case, DIC is used as a tool to gain process insight, but this time based on thickness measurements.

CASE 3: DIC for Accurate Impact Measurement of Pattern Heating on Wall Thickness Distribution

A way of locally influencing locally the final thickness is to keep parts of the mold at a lower temperature to ensure that once the material touches these cold parts, it freezes immediately. The ultimate aim is to locally limit thickness reduction. In fact, this strategy results in two opposing effects. On the one hand, the cooler zones will locally reduce the friction coefficient (or improve slip), i.e. the opposite of the desired effect. On the other hand the lower temperature of the sheet increases the local resistance to deformation. Which one of the two effects will prevail is not easy to predict since it depends on the temperature difference between the mold and the sheet, the initial thickness and material of the sheet (affecting the heat transfer), the process speed and the temperature dependence of friction coefficient and yield stress. Moreover, this approach has the disadvantage that it only affects the forming step which is most of the times very short and that it relies on the fact that the sheet needs to cool down locally during that short period of time. Eventually, it will lead to chill marks or even in worse case to open tears. The positive aspect of this approach is that the location of the cooler zones can be defined quite precisely.

Patterned or zoned heating, i.e. non-uniform in-plane heating of the sheet, is a second technique to acquire thicker of thinner zones in the final product [21]. Although this technique is not new, it is not so much used since it adds complexity to the process control. Besides, it is often not clear which effect causes a certain final thickness distribution since by applying zoned heating, the final thickness is affected in every step of the process from heating (sagging), bubble inflation (when applicable), to forming. By combining thermal measurements with in situ DIC we are able to create full field strain maps clarifying which process step is responsible to which extent of the thinning. Moreover, the link between the initial position of the sheet below a specific zone of heating elements and the final position after forming can easily be tracked, making the process setting more straightforward.

In this third application, a suitcase shell is formed over a male mold. Bounding box dimensions are mentioned in Table 1. Since it is a male mold, a bubble is inflated right before the forming step. In a first step the sheet is formed with a standard symmetric heater setting of 300°C. The pressure necessary for the bubble is adjusted until a height of 160 mm is reached, which is equivalent to the mold height, ensuring that the best possible thickness distribution is acquired without forming wrinkles. Since in parallel, stereo digital images for DIC calculations are taken throughout the whole process, we are able to visualize the 3D shape of the symmetrically heated sheet after sagging, after bubble inflation and finally after forming (Figure 8).

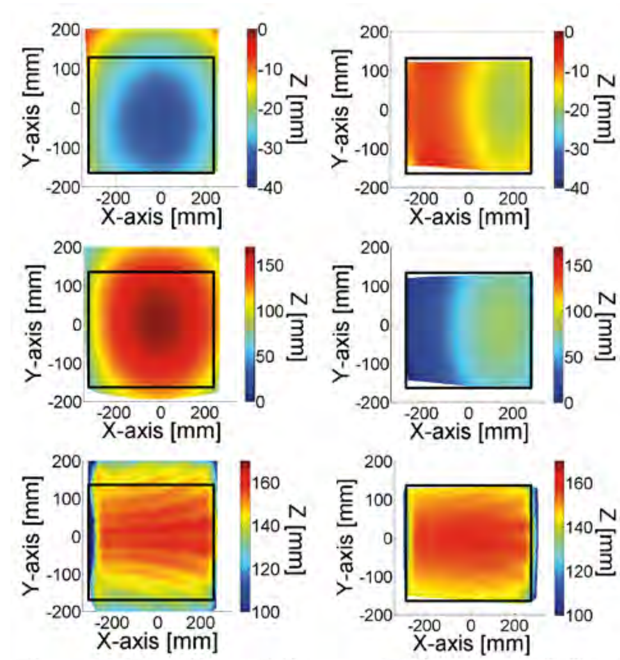


FIGURE 8: *Top-view of the sagged sheet (top), inflated sheet (middle) and formed sheet (bottom), symmetrically heated (left) and asymmetrically heated (right).*

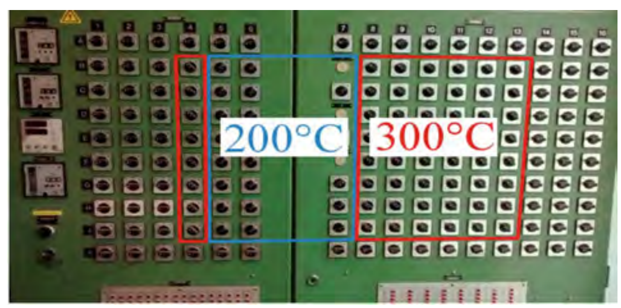


FIGURE 9: *Asymmetric heater setting. Each switch controls a ceramic heating element.*

In order to visualize the effect of the asymmetric heating a thermal image is taken right before forming (heating time: 120 s, hottest section of the sheet reaching 150°C) with a FLIR T335 infrared camera with an emissivity setting of 0.96 (Figure 10). In analogy to the description above, the shape can again be visualized at different points throughout the process (Figure 8, right column). The difference in the size of the represented area between the symmetric and the asymmetric heating is due to the choice of the region of interest during the DIC calculations and has no influence on the overall result.

Some of the findings are obvious. For example, the sagging of the symmetrically heated sheet is symmetric and much more pronounced than that of the asymmetrically heated sheet. The same applies for the 3D shape after the bubble inflations step: the bubble is higher in the case of symmetric heating. The final shape of the formed product is in both cases comparable, meaning that

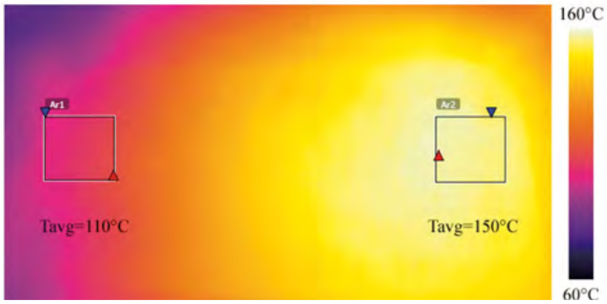


FIGURE 10: *Thermal image of the sheet right before forming. The area that is represented corresponds to the top surface of the suitcase.*

the mold is adequately reproduced. These findings are as expected and can be related to the difference in temperature and, therefore, the difference in material stiffness.

When analyzing the thickness profile of a horizontal cross section through the middle of the part at the same time intervals as described before, the result for the asymmetrically heated product is clearly asymmetric where that of the symmetrically heated product is almost flat (Figure 13). Since measurements are performed during the process, it is easy to attribute the thinning to a specific part of the process. In this case, half of the final thinning (when considering the thinnest final zone) is caused by the asymmetric sagging (from 1 mm to 0.8 mm, Figure 11), an extra 25% is caused by bubble inflation (from 0.8 mm to 0.7 mm, Figure 12) and finally the last 25% is caused by the forming process during mold contact (from 0.7 mm to 0.6 mm; Figure 13). On the other hand, the cold side (left part of the cross section) is almost not strained during sagging or bubble inflation since in these steps the available force (gravity and bubble inflation pressure (<10 mbar)) is too low to induce deformation. Furthermore, it is only slightly strained (thinned) during the forming step. This demonstrates the detail that can be achieved with the proposed stereo-DIC technique, information that could otherwise only be obtained through complex through-process finite element modelling. As a comparison, the thickness profiles of the symmetrically heated sheet are also shown on the same figures and are represented by a green line. From these cross sections we can see that the forming on itself hardly affects the final thickness and that the bubble inflation and the sagging are almost entirely responsible for the final thickness distribution of the top surface of the suitcase.

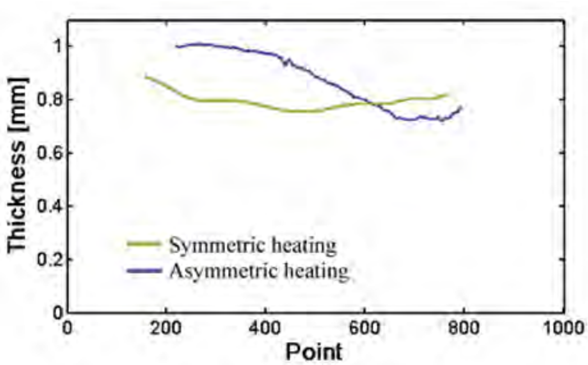


FIGURE 11: *Thickness distribution of a central horizontal cross section after sagging.*

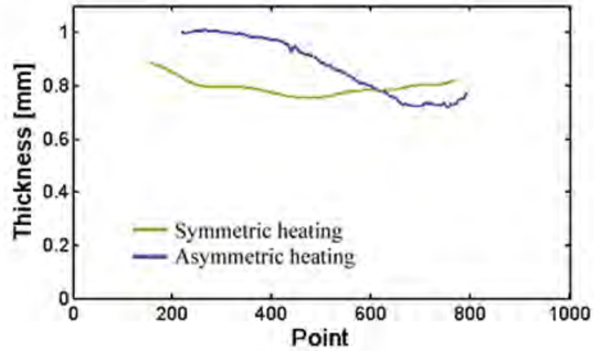


FIGURE 12: *Thickness distribution of a central horizontal cross section after bubble inflation.*

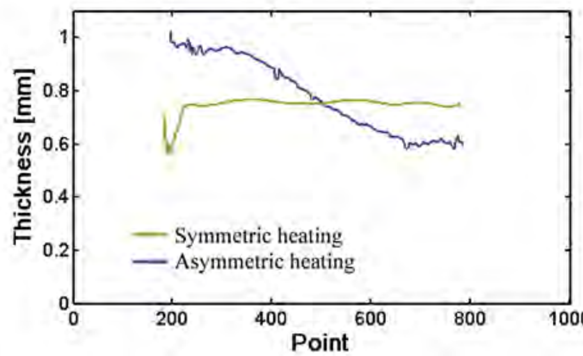


FIGURE 13: *Thickness distribution of a central horizontal cross section after forming.*

A drawback of zoned heating is that the location of the hot or cold spots cannot be specified as accurately as it is with the technique of cold spots in the mold. However, new techniques are being developed that allow a very precise local control of the temperature [22, 23]. Also, the attainable effects with control of heating elements in state-of-the-art thermoforming machines have not yet been explored in detail in view of zoned heating.

Conclusions

Detailed insight in the forming process is an essential aspect in making high quality thermoformed parts. Until now, this insight is rather limited, especially for heavy gauge thermoformed products. This paper illustrates how digital image correlation can help in improving process insight on different aspects of the process. This is illustrated for three different cases. The first case explains the potentials of the 3D reconstruction during each thermoforming step. The second elaborates on the measurement of full field wall thickness distribution. The third case shows that DIC can be used to identify the contributions of each process step to the heterogeneous the thinning of a sheet. This is demonstrated on a product were zoned heating is applied. The adopted methodology provides more process insight, making it easier to determine the process parameters that should be modified and by which extent to control the final thickness distribution. Moreover, by combining new techniques for localized zoned heating with DIC, we believe that the process can be drastically improved, leading to faster product setup and easier fine-tuning of the machines.

Acknowledgement
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Developments to Compound PE/PP with Fillers and Extrude Film/Sheet for Thermoforming in One Step

By Charlie Martin, Leistritz, Somerville, NJ

Design advancements for high speed, energy input (HSEI) twin screw extruders (TSE's) offer new opportunities to compound PE and PP with fillers and additives. Historically, this device has produced a pellet that is then fed into an injection molding machine or single screw extruder. It is now common to by-pass pelletization and to directly extrude a film or sheet (or another type of part) for thermoforming in one-step to realize conversion and energy cost savings. Many thermoformed products also benefit by experiencing one less heat/shear history inherent with the "direct extrusion" process, such as HDPE/conductive black laminated sheeting, as is commonly used in the electronics industry.

Direct extrusion systems require integration of material handling and feeding equipment with a starve-fed mass transfer continuous mixer (the HSEI twin screw extruder) and a gear pump mated to a die. Melt temperature plays a more important role and the system is more complex. The die/downstream system will be the same as if a single screw extruder was processing a pre-compounded pellet.

HSEI Twin Screw Extruder Theory and Design Basics
HSEI twin screw extruders utilize segmented screws that are assembled on high torque splined shafts. Barrels are also modular and utilize liquid cooling. The motor inputs energy into the process via rotating screws that impart shear into the materials being processed. Segmented screws/barrels, in combination with the controlled pumping and wiping characteristics of the co-rotating, self wiping screws, allows screw/barrel geometries to be matched to the process tasks. Solids conveying and melting occurs in the first part of the process section. Screw elements for mixing and devolatilization are then utilized as dictated by the process. Discharge elements then build and stabilize pressure to the die or front-end device.

FIGURE 1: *HSEI Co-rotating intermeshing twin screw extruder screw set*

The free volume in the process section is directly related to the OD/ID ratio. The OD/ID ratio is defined by dividing the outside diameter (OD) by the inside diameter (ID) of each screw. The torque limiting factor for a HSEI twin screw extruder is the screw shaft based upon its cross-sectional area, the geometry of the shaft, the material of construction and the fabrication techniques. Deeper screw flights result in more free volume, but with less torque, since a smaller diameter screw shaft is mandated. Based on the use of a symmetrical splined shaft, a 1.55 OD/ID ratio has generally been deemed to offer the best balance of torque and volume.

HSEI twin screw extruders are starve fed, with the output rate determined by the feeder(s) which meter pellets, liquids, powders and fibers into the process section. The extruder screw RPM is independent from the feed rate and is used to optimize compounding efficiencies. Because the pressure gradient is controlled, and zero for much of the process, materials are easily introduced into downstream barrel sections to facilitate sequential feeding.

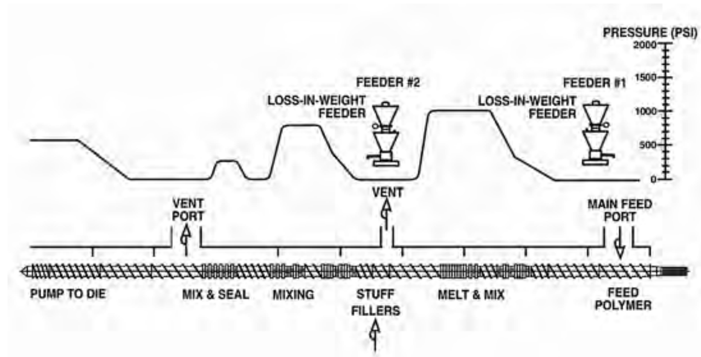

FIGURE 2: *Pressure gradient in a HSEI twin screw extruder*

Most HSEI TSE's produce pellets, with minimal regard to dimensional stability. Combining compounding/devolatilizing with direct extrusion can be challenging, in that high mass transfer operations must be coordinated with consistent pumping. The HSEI TSE process section is typically lengthened so that the latter sections of the screws are dedicated to pumping, and a gear pump is used to build and stabilize pressure to the die. A screen changer for filtration is also commonly integrated into the front-end system.

The system generally requires a programmable logic controller (PLC) to implement a pressure control algorithm program that analyzes inputs from key points in the system, makes numerical calculations, and applies corrections to the screw RPM, gear pump RPM and feed rate. The residence time for the materials in a HSEI TSE process section must be factored into the pressure control algorithm. The goal is to maintain a low/consistent gear pump inlet pressure, without cavitation, to optimize the film/sheet quality.

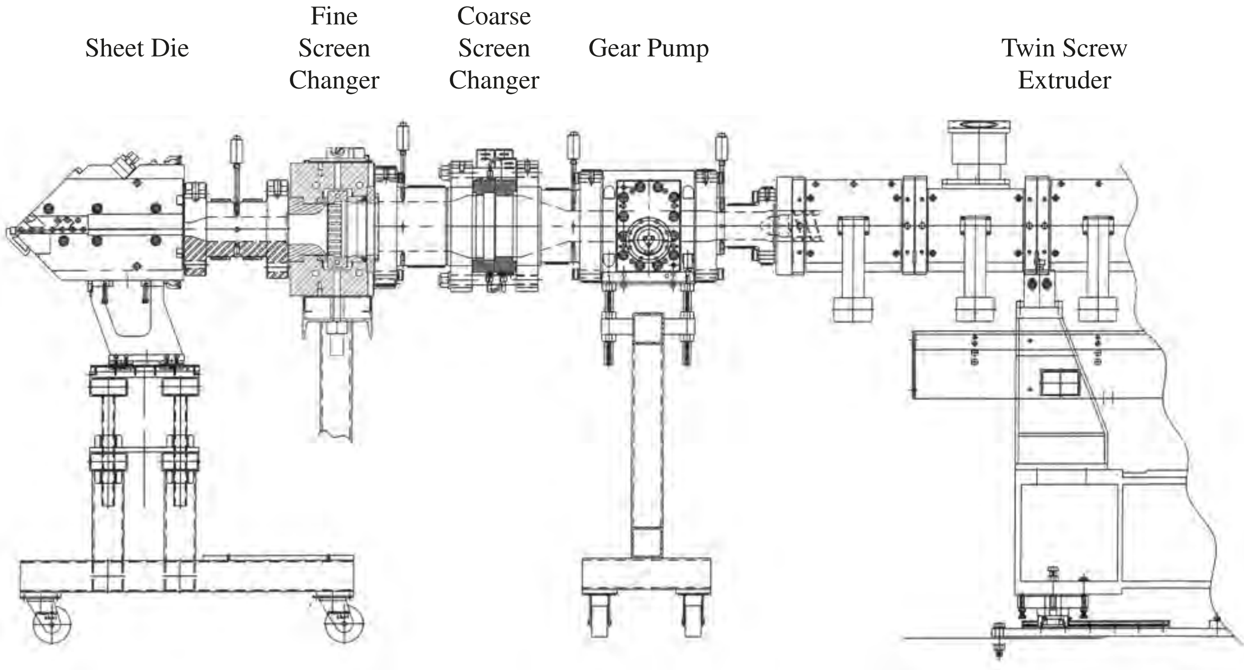

FIGURE 3: *Direct sheet extrusion front-end assembly with gear pump and multi-stage filtration*

HSEI Twin Screw Extruder Advancements for Increased Free Volume and Higher Torque

A new asymmetrical splined shaft has improved power transmission efficiency so that a smaller diameter shaft can transmit 30% higher torque than before. This is accomplished by isolating the tangential force vector from the motor into the shafts/screws. The combination of both higher torque and larger OD/ID ratio has proven beneficial for many processes.

In Leistritz nomenclature its HP series has a 1.55/1 OD/ID ratio, and the MAXX series a 1.66/1 OD/ID ratio. Increasing the OD/ID ratio increases the free volume by approximately 30% and that corresponds with slightly larger OD and slightly

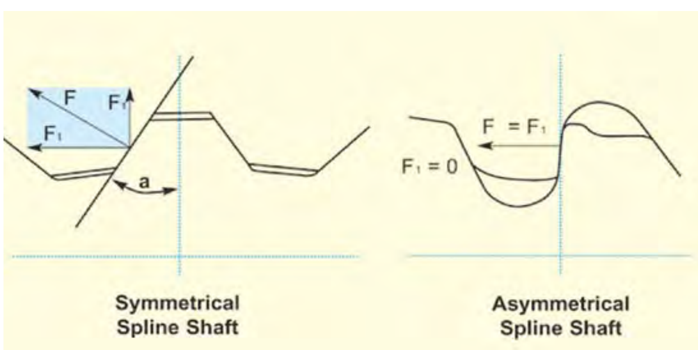

FIGURE 4: *Comparison one-tooth of symmetrical and asymmetrical screw shaft geometries*

smaller inside ID. The image below indicates a 1.55/1 OD/ID as compared to a 1.66/1 OD/ID ratio, as well as the asymmetrical tooth design.

The higher tip speed inherent with a larger diameter screw diameter for the MAXX design also results in an increased peak planar shear value for the 1.66/1 OD/ID geometry . For instance, a HSEI TSE with a 75 mm OD and 1.55/1 OD/ID ratio would

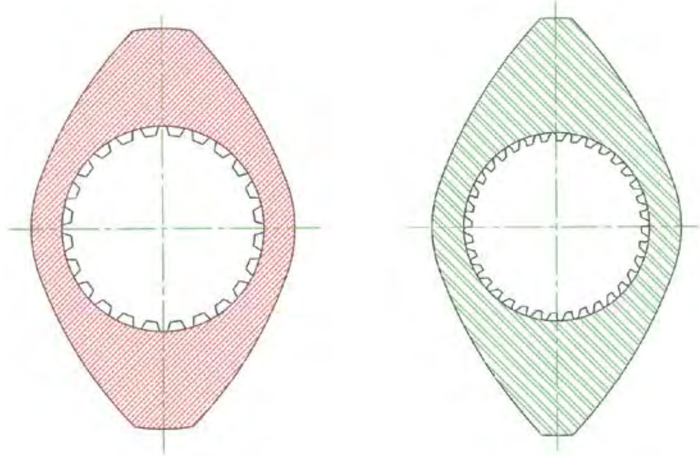

FIGURE 5: *End view HP and MAXX screw element geometries*

It must be noted that peak planar shear is merely a benchmark for dispersive mixing capability, as it does not take into account the extensional shear effects, directional flow changes, and pressure fields that are also components of dispersive mixing.

Experimental Data Comparing HSEI Twin Screw Extruders with 1.55/1 and 1.66/1 OD/ID Ratios

Experimental data has been generated comparing 1.55/1 OD/ID with 1.66/1 OD/ID model HSEI TSE's with process sections that are interchangeable and mated to the same gearbox. Initial tests were performed with a neat resin with a 40/1 L/D process section and 50 HP motor:

LDPE Powder: LDPE powder feedstock with a 12 MFI was processed on ZSE-27 HP (27 mm dia. screws, 1.55/1 OD/ID and 10.3 cc/dia. free volume) and ZSE-27 MAXX (28.3 mm dia. screws, 1.66/1 OD/ID and 14.3 cc/dia. free volume) models. The

1.66/1 OD/ID ratio made it possible to feed more material to the extruder before encountering feed limitation. In each instance, the rate limiting factor was the volumetric feed capacity. The process was not torque limited. The increase in achievable feed rate was comparable to the increased free volume associated with the 1.66/1 OD/ID ratio as compared to the 1.55 OD/ID ratio at screw rpm's of 600 and below. At elevated screw rpms (greater than 800) the percentage increase was not as pronounced, as the higher screw tip velocity seemingly has a "propeller" effect that inhibits feeding.

The corresponding melt temperatures were lower for the 1.66/1 OD/ID ratio (at the higher rates) due to a lower specific energy input (kW) into each kg being processed and the gentler mixing effect associated with the 1.66/1 OD/ID screw geometry. For example, there is a lower shear rate in the channels and the material experiences less residence time in planar shear in the kneader sections.

Subsequent tests were performed comparing the ZSE-50 HP and MAXX models for formulations that were either torque or volume limited with the following results:

Fractional melt HDPE with carbon black (CB) masterbatch: Both pellet feed streams were metered into the main feed throat of ZSE-50 HP (50 mm dia. screws, free volume 70 cc/dia. and 1570 NM torque rating) and ZSE-50 MAXX (51.2 mm dia. screws, free volume 86.3 cc/dia. and 2144 NM torque rating) models via two (2) loss-in-weight feeders. The formulation was 93% HDPE (Lupolen 5021DX) and 7% CB masterbatch with 40% CB content. The ZSE-50 MAXX was able to process approximately 25-40% more throughput rates with equal or better mechanical properties. All achievable rates were torque limited.

Split feed PP with 80% CaCO3: A formulation of 20% PP(Moplen EP 448 T) and 80% CaCO3 (Omya BSH OM) was processed on ZSE-50 HP (50 mm dia. screws, free volume 70 cc/dia. and 1570 NM torque rating) and ZSE-50 MAXX (51.2 mm dia. screws, free volume 86.3 cc/dia. and 2144 NM torque rating) models. The PP was metered into the main feed throat. The CaCO3 was introduced sequentially into the main feed throat and via two (2) downstream side stuffers. In total, five (5) loss-in-weight feeders were used as part of the system.

The ZSE-50 MAXX processed this formulation with approximately 30% higher throughput rates with an equal quality product. All rates were volume limited, not torque limited.

Direct extrusion of film/sheet from a HSEI twin screw extruder: Almost without exception, direct extrusion applications require developmental efforts. As an example, testing was performed to compound PP (2 MFI) with 40% CaCO3 to develop a system configuration and process conditions to take raw ingredients and to convert them into a film/sheet product. The following reflects the equipment utilized with the test conditions and comments relative to each device:

Loss-in-weight (LIW) metering feeders: The LIW feeders metered the PP (60%) and CaCO3 (40%) into the main extruder feed throat and downstream via the side stuffer. No additives/dispersive aids were used, which can benefit the process. Split feed streams require LIW feeders, as compared to volumetric control, to the maintain formulation accuracy and also to help maintain pressure stability.

ZSE-27 MAXX (28.3 mm dia. screws), 1.66/1 OD/ID ratio, 40 to 1 L/D, and a torque rating of 304 NM (both screws): A mid-range screw rpm (600 rpm) was selected to optimize process conditions. A medium intensity screw was selected to mix the fillers/PP. The barrels layout (10 barrels) included an atmospheric vent in position #4, provision for side stuffing in position #5, and an additional vent in position #8. Barrels #9 and #10 were solid before the gear pump.

LSB Side stuffer: The side stuffer is a co-rotating, intermeshing twin auger device that, as the name implies, "pushed" the CaCO3 into barrel position #5 in a positive manner. The rate of the filler is set by the LIW feeder, not the side stuffer. The extruder screws at the side stuffer position were selected to accept the filler material, provide a relief vent for entrapped air and moisture that was being flashed, and to drive the CaCO3/PP melt over mixers.

Gear pump front-end attachment: The gear pump is a positive displacement pump that is designed to increase and stabilize pressure. This device allows the HSEI TSE to perform mass transfer operations (mixing and devolatilization) with less emphasis on pumping stability. By allowing the HSEI TSE to operate with a lower front-end pressure, there is significantly less overflight mixing and viscous heating at the extruder discharge, which results in a lower melt temperature. During the testing, the gear pump inlet pressure was approximately 400 PSI, with a fluctuation of +/- 80 psi. Gear pumps are typically rated for a 4000 PSI pressure differential and dampen pressure fluctuations by approximately a factor of 10.

Screen changer: A slide plate screen changer with a 100 mm dia. breaker plate and 300 mesh screens was used. Filtration was performed after the gear pump because of the filtration level and to maintain a low front-end pressure and melt temperature. If coarser filtration levels are opted and/or if there are high levels of contaminants in the melt stream then the screen changer should be situated before the gear pump. Filtration can be a tricky part of a direct extrusion system and needs to be thoroughly investigated. Reclaim materials sometimes require filtration both before and after the gear pump.

Flexible lip sheet/film die: A 750 mm wide flexible lip sheet/film die was used that allowed the die lips to be contoured for gauge control. The die gap was set at ½ mm to extrude films with thicknesses of 100 and 250 microns. The die manifold was a coat hanger type designed for general lab work and was not optimized for the materials being processed. In a production setting, the internal manifold geometry is designed based upon computer modeling reflecting rheological, shear rate and temperature data.

Downstream take-off: A 3-roll stack with 40 inch wide and 12 inch diameter double shell spiral baffled rolls with liquid

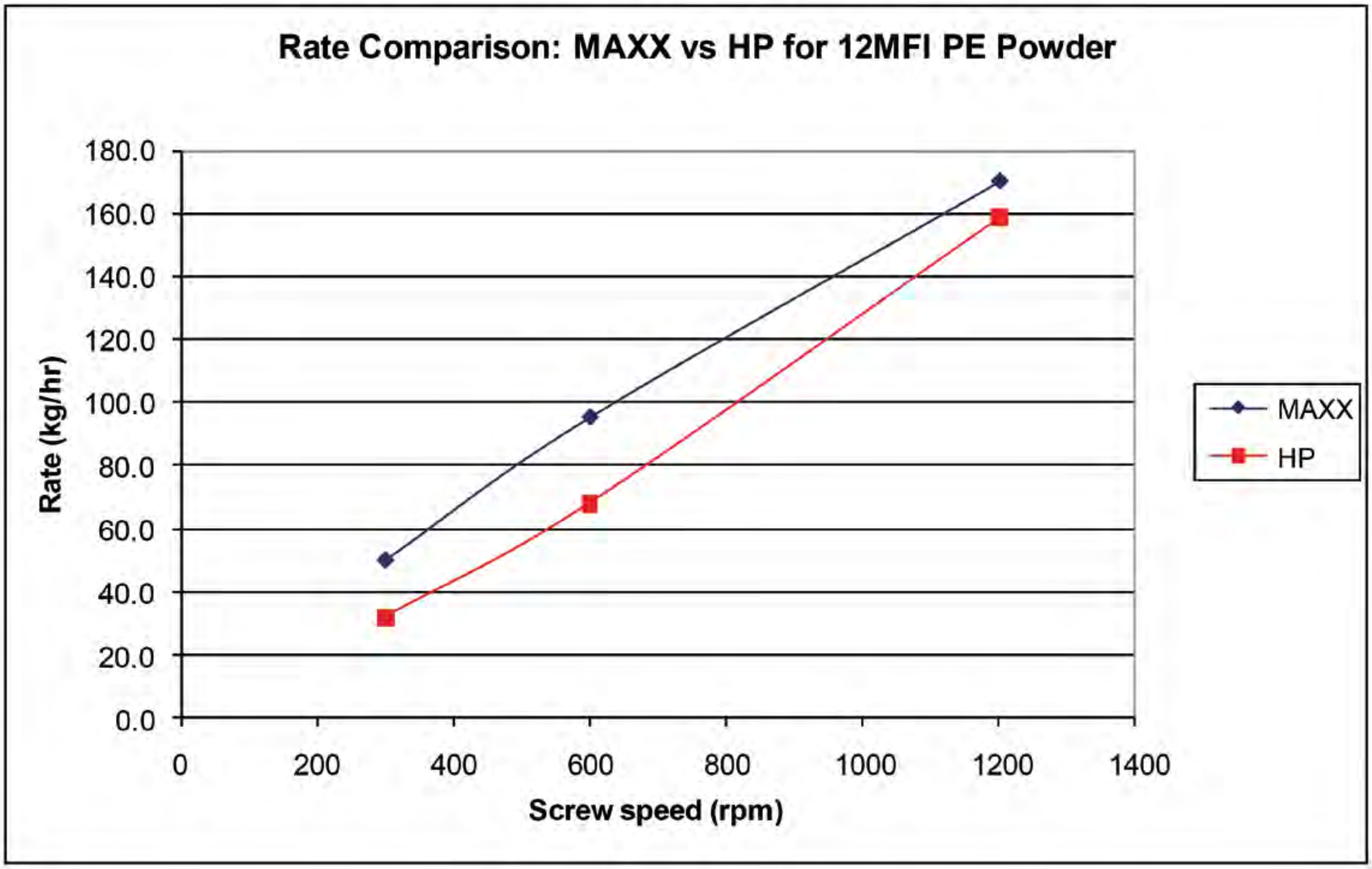

FIGURE 7: *Rate Comparison: MAXX vs HP for 12MFI PE Powder*

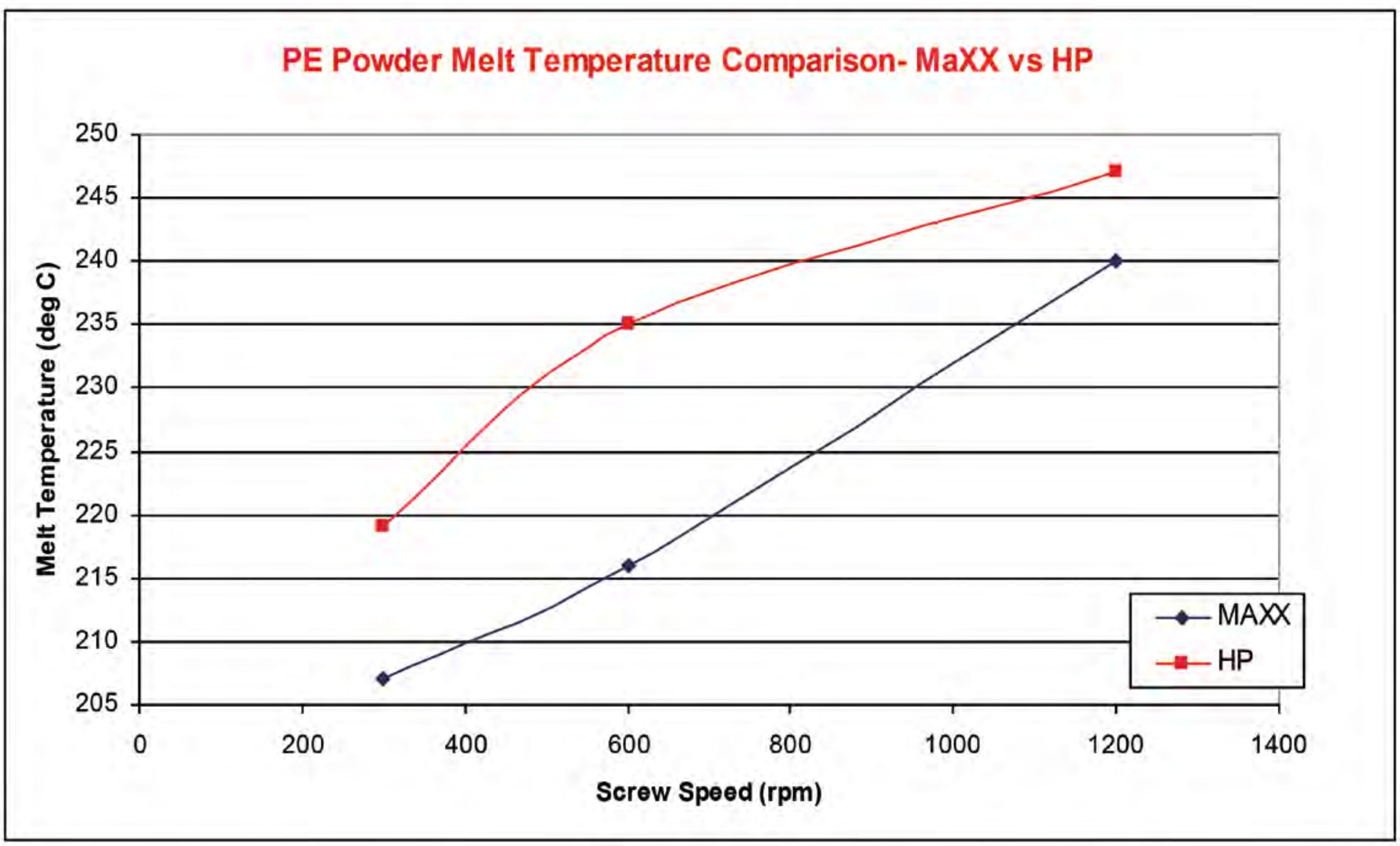

FIGURE 8: *Melt temperature comparison: MAXX vs HP for 12 MFI PE powder*

temperature control was used to pull, size and cool the film. A pull roll station maintained film tension prior to a simple torque winding station. Sheet/film take-off units are made in many different configurations, such as vertical stack, 45º canted stack, and horizontal stack.

Test summary: The tests were run at 70 kgs/hr and 600 screws rpm. The temperature zones for the barrels were set between 200 and 220 deg. C, and the downstream zones were set at 222 deg. C. The motor load was 67% and the melt temperature measured 225 deg. C. As denoted above, the gear pump inlet pressure was 400 PSI, +/- 80 psi. Analysis of the film/sheet samples indicated a well-dispersed product with acceptable surface quality and dimensional stability, given the limitations of the die and downstream system utilized.

Previous test runs were performed at 45 kgs/hr to refine operating conditions before increasing the rate, and the testing occurred over three-days, excluding set-up and clean-up, which is typical for a lab test of this scope. The viability of the direct extrusion process for this formulation was, essentially, confirmed by the tests. A series of trials are generally performed, including scale-up runs on larger equipment, to define the scope of the eventual production system.

Summary

HSEI twin screw extruders are widely used to process highly filled PE/PP compounds into pellets and film/sheet. New HSEI twin screw extrusion advancements offer new opportunities to compound polyolefins with fillers, which can then be applied to the direct extrusion of film/sheet for a better thermoformed product at a reduced cost. Whatever the final part, it is important for processors to be aware of and to implement the latest technologies, as appropriate, into their manufacturing operations.

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Thanks to the SPE Extrusion Division for contributing this article.

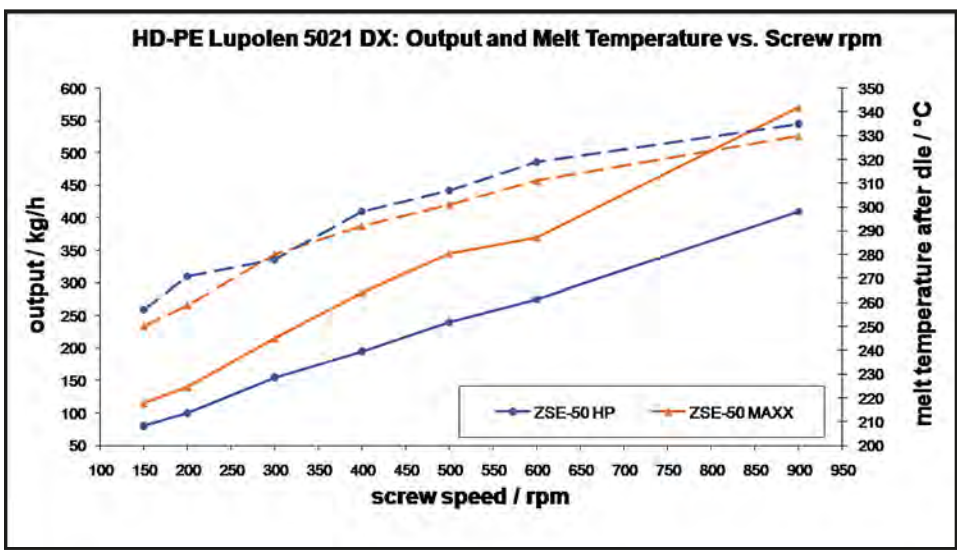

FIGURE 9: *HDPE & CB Masterbatch: ZSE-50 MAXX vs HP Output & Melt Temperature vs. Screw RPM*

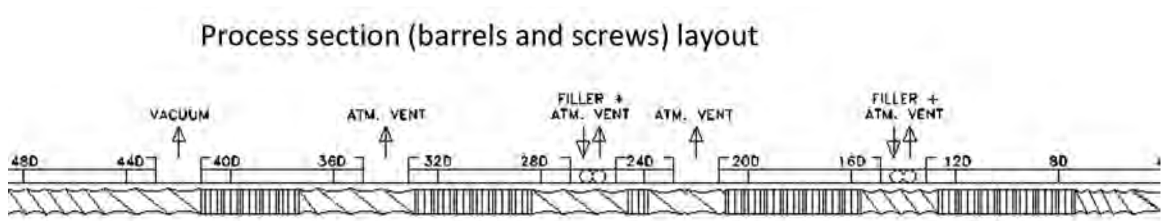

FIGURE 10: *ZSE-50 HP vs MAXX: Polypropylene with 80% $CaCO_3$*

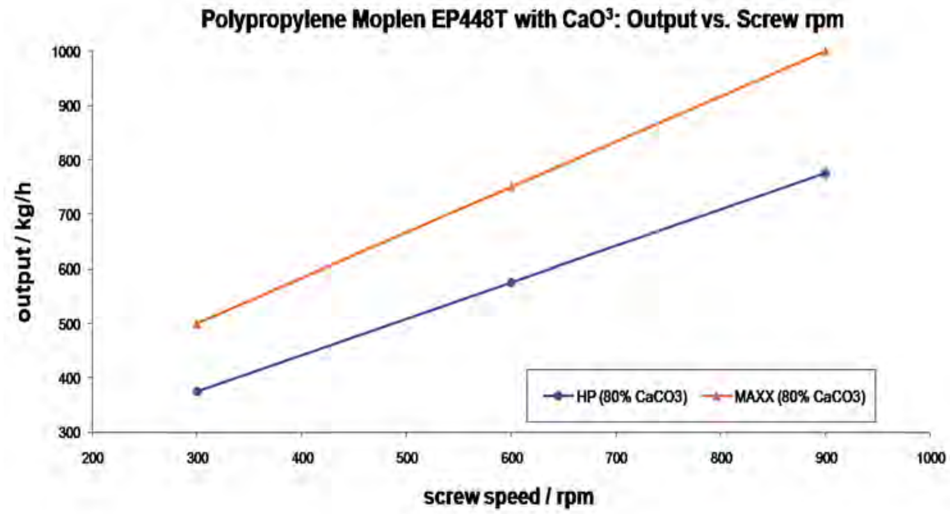

FIGURE 11: *Comparative throughputs ZSE-50 HP vs MAXX: Polyproylene with 80% CaCO3*

Need help with your technical school or college expenses?

If you or someone you know is working towards a career in the plastic industry, let the SPE Thermoforming Division help support those education goals.

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In Memoriam · Jack Pregont

4/29/1929 – 4/17/2015

Prent Corporation is saddened to announce the death of Jack E. Pregont, 85, founder of the company and Chairman Emeritus. Jack was born April 29, 1929, in Wausau, WI, the son of Elmer and Esther (Treu) Pregont.

"The passing of my father is a sad loss for this company and my family," says his son, Joseph T. Pregont, Prent President and CEO.

Jack Pregont founded the privately held thermoform plastic company in 1967. Fifteen years later he founded GOEX Extrusion, an extruder of plastic sheet and rolls stock.

Today Prent Corporation is a leading global manufacturer of thermoform packaging for the medical industry and a fast-growing leader in packaging for the electronics and consumer industries. Headquartered in Janesville, WI, USA, Prent employs over 2,000 people at nine facilities in Janesville WI, Singapore, China, Malaysia, Puerto Rico, Costa Rica, Denmark and Arizona.

A Pioneering Leader in Thermoforming

Over the past half century, Jack Pregont was recognized as one of the founders of modern thermoforming. In 1980 he and six others created the "Thermoforming Institute" of the Society of Plastic Industry (SPI) and he served as the organization's first Chairman. In 1989 he was named "Thermoformer of the Year" by the Society of Plastic Engineers (SPE) and in 2007 the Thermoforming Division of SPE honored him with their "Lifetime Achievement Award" for his significant contributions to the plastics industry. Thanks to Jack's leadership, Prent is renowned today for its design, engineering and production excellence.

As a company owner, Jack believed in paying fair wages, providing advancement opportunities, intensive training and generous benefits. In 1968, he developed the Mini-Shift employment concept, since copied by many manufacturers and featured in business publications. When a local newspaper mistakenly ran a Prent Help Wanted ad under "part-time work" rather than "full-time." hundreds of applicants were waiting in the parking lot the next morning. So, he decided to create a four-hour, part-time production position, calling it a Mini-Shift. Among the generous benefits was the ability to take the entire summer off to be with their school children, plus take time off for family events. Today, the Mini-Shift is still going strong and is a highly sought employment opportunity. In 1977, Jack also began an employee profit sharing plan, which has benefitted hundreds of loyal employees.

The Budding Entrepreneur

The son of a retail baker in Janesville, WI, Jack Pregont pointed to 1948 as the year his interest in plastics first began. A neighbor gave the teenage boy a stack of old Popular Mechanics. One magazine article in particular caught his attention: it was about how celluloid ping-pong balls were made.

"As far back as I can remember," he said, "I was scrounging around for pieces of plastic to mold. My mother's kitchen oven was my heat source and she complained about that for the rest of her life!"

Most of his early projects were bakery-related, which evolved into a line of mail order cake decorating novelties. Later, when he was developing a thermoformed plastic merry-go-round, the new owners of the Janesville Paper Box Company suggested he develop plastic packaging for them on a commission basis. In return he would be allowed to use their forming equipment to produce his merry-go-round. Within three years, the plastics department exceeded the box business.

Frustrated by the lack of time to thermoform his projects, Jack left the company. But just as he was ready to strike out on his own, the Janesville-based Parker Pen Company asked Jack to join its executive training program.

He did, and never regretted the decision. "During my seven years with Parker, I gained invaluable experience traveling and doing everything from sales promotion to working with Parker's automation subsidiary," he explained.

Meanwhile, Jack continued to moonlight in the basement of his parent's bakery thermoforming current fads for birthday cake decorations and selling plans for a simple thermoforming machine—through ads in *Popular Mechanics*. By 1966, the profits he earned selling Batman cake decorations allowed Jack to buy an old 10,000 sq. ft. silo factory. He acquired two beat up forming machines from the Rubber Maid Company junk pile, updated them to a competitive level and cleaned up the building. Finally in November 1967, Prent Corporation was open for business with 15 employees.

Success came quickly to Jack. After three years, Prent's employment doubled and Jack was able to establish model and tool departments. After four years, Jack received his first packaging award, beginning a nearly 50 year track record of major packaging achievements, including 15 prestigious World Stars. And after just six years in business—with sales doubling every year and employment reaching 100— Jack was running out of room in his old silo factory. By 1974, he had constructed and moved into a new state-of-the-art thermoforming facility.

Jack retired in 1985 and his son Joseph T. Pregont became President. Today, Joe's children, Joseph II, Rachael and Michael, have all followed in their grandfather and father's footsteps and are actively involved in leading Prent and GOEX well into the future.

Carolina Color Introduces New G3 Line of Colorants

By www.carolinacolor.coms

Carolina Color Corporation introduces its new G3 line of colorants. Carolina Color is a successful, family-owned company since 1967 that serves colorant needs from ISO 9001:2008-certified locations in North Carolina and Ohio.

In 2008, the company patented "G2", an innovative product in which pigments and additives are highly loaded, exceptionally well-dispersed and can effectively distribute in both large and small parts. Building upon the strength of G2 in the marketplace, Carolina Color has developed its next-generation G3 product line.

Key attributes and advantages of using G3 include:

- Can be used in all olefins and engineering resins
- Provides higher pigment-loaded custom colors
- Lowers environmental impacts with a reduction in production energy, packaging materials and C02 emissions
- Supports six sigma and lean production methods

Carolina Color's G3 product line will be effective in diverse applications such as packaging, housewares, lawn & garden and transportation. G3 technology can be applied to most major polymers including acrylic, PET, PS, ABS, TPO and high-gloss materials.

Convertors will be impressed by the new G3 technology, whether performing injection, blow molding or extrusion. Some extruders have already reported an increase of 15% in input rates.

Jeff Smink, President of Carolina Color stated: "We are thrilled to introduce this next generation product line and we anticipate broad-based adoption by the industry. G3 is another example of our ability to create truly disruptive technologies that provide our customers with real competitive advantages. What I find particularly exciting is that G3 offers pigment loadings that eclipse any other colorant technology out there, including liquid. To be able to deliver colorant that efficiently and in a solid pellet form is a game-changer."

Carolina Color's North Carolina and Ohio locations provide customers with full-service production capabilities and complete laboratories for color matching, testing, and analytics.

Formulation	G2 Version	G3 Version	% Loading Increase	Liquid let-down ratio	G3 Let down ratio
Red for PP closure	29% Organic pigment mix	35% Organic pigment mix	20%	0.65%	0.3%
Lightfast PE Green	28% Organic pigments 20% Inorganic	34.5% Organic pigments 24.6% Inorganic	23%	0.75%	0.25%
Blue Pearl for PP closure	16% Pearl 9% Phthalo Blue	29% Pearl 16% Phthalo Blue	85%	0.8%	0.5%
Lavender Pearl w/slip agent for PE closure	35% Pearl 5% Slip Agent	53% Pearl 7.5% Slip Agent	50%	0.9%	0.5%
ABS Yellow for sheet	11% Organic pigments 4.5% Dye*	27.5% Organic pigments 11% Dye	145%	Not compatible	1%

**Note: typically, G3 formulations process at a higher throughput than G2.*


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COUNCIL SUMMARY

Roger Kipp
Councilor

The Business of SPE

Over the past six years in my capacity as the Thermoforming Division Councilor, I have focused on communicating the strategy, planning and activities that SPE has undertaken to expand member value. In preparing to communicate this article—my final message for the Quarterly as the Division Councilor— I thought it would be a good time to bring the membership up to date on some of the recent business aspects of the Society.

I want to thank Andy McGary, SPE Europe, for filling in as my proxy at the SPE Council on 03/22/15 and providing me with copious notes from those meetings.

2014 Highlights

• SPE realized positive results of $103k against a budget of negative $86k. This was a real achievement under difficult market conditions. At the same time, the organization was able to develop and execute a number of new projects.

o Revenue achievements include:

• Membership dues in-line with budget, although the number of new members still declining very slowly

• Advertising revenue increased 20% primarily related to increased web site ads

• Events revenue increased 20%–mainly due to Antec Dubai and webinars

• Publications increased +2% related to advertising sales in *Plastics Engineering*

o Expense reductions over previous year:

• Membership acquisition/marketing is down by 45%, in part because we are sending less renewal mail

• Event costs were reduced by 12% (no K-show expenses)

• Accounting audit

o Draft audit report received from Auditor 3/15 and approved by the Finance Committee on 3/21

o An audit copy is available for your review in Leadership Lane on The Chain

• Cash balance: $1.2MM start of year vs $1.35MM end of year

o The overall financial situation is good and cash has been managed efficiently. This is essential to ensure continued investment in new technologies and to generate new income streams.

In order to ensure the future of SPE, the leadership has focused on systems and tools that may not have traditional financial ROI but will yield long term value. These include:

1. Expanded use of digital technology

• Reduces member loss & attracts new people to SPE

• Addresses generational gaps

• Provides expansion and sharing of resources

• Develops alternative revenue

• Significant investments in the period are as follows:

• Account Management System (AMS) upgrade ($100k)

o Successful upgrade to a more capable & flexible AMS

o Allows for an easier join and renew process

o Improved reporting systems

• The enhanced events module effort in 2014 was unsuccessful primarily in the area of registration. For 2015, SPE is partnering with e-touch for improvement. The Automotive and Composites Divisions, the Vinyl Division and the Detroit Section are already committing to take advantage of this improved system.

2. New website: $130k investment

• Modern look & feel

• Mobile responsiveness

• Easier navigation

• Centralized and fully searchable database

• Increased traffic and decreased bounce rate (people who visit and leave within 3-4 seconds)

3. The Chain - $30k

• Project continues with Leadership Lane, Tech Talk, and Campus Connection networking

• Sales of advertising has started

4. The Foundation

• Focus on growth with an emphasis on workforce development

• 35 scholarships awarded in 2014 valued at over $100,000

• Goal to double over next 3 years

• Electronic application created for 2015 to improve the application process

• Increased promotion and communication to students

• Increased communication and promotion to Sections and Divisions encouraging Foundation Scholarship participation

• $32K grants reviewed

• Increased PlastiVan® visits in 2014

• A positive financial performance from the PlastiVan program

• A new business plan for PlastiVan expansion has been developed and is now in action

• The National Plastics Center and Museum donated $250,000

• Continue to address the workforce skill gap initiative

• ACC *Hands on Plastic* skills to further support STEM in schools across North America

SPE is not a profit-making organization but it does needs profitability to exist. Future financial streams can only be realized if we consider the right membership options. We need to ensure that we reach lots of people or 'represent' lots of people. This is why we need e-membership. Social media has thrived through free membership and sponsorship.

Why does SPE need to make these investments and implement change? To guarantee our sustainability and ensure we are still here in 20 years. If we remain relevant to the plastics industry, we will be sustainable. Initiatives like corporate training and The Chain will promote engagement. Sections and Divisions need to seek out new young professionals and get them on board. We can all help!

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Join us in Sitges, Barcelona where we will be celebrating 20 years of the ETD supporting your industry, you will be most welcome.

Questions?
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SPE

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    - Publications – Paul Uphaus

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TQ Magazine's Advertising Sizes to Change in Third Quarter

In an effort to provide more advertising value to our sponsors, *Thermoforming Quarterly* is changing its advertising sizes. The new sizes will give sponsors more square inches than previous sizes. For example, a current Silver Ad is 4.75" x 3" or 14.25 square inches. The new Silver Ad size will be 3.65" x 4" or 14.6 square inches. Gold sponsors will get a choice of two ad sizes as shown below. Platinum sponsors will see no change and still receive a cover position (inside front, inside back or back cover) and measures 8.75" x 11.25" which includes the necessary page bleed. Also not changing is the Titanium Ad size which is currently 8" x 10.5" with no bleed.

New Ad Sizes in a Nutshell

Platinum	Cover	8.75 x 11.25" (includes bleed)
Titanium	Full Pg	8 x 10.5" (no bleed)
Gold		7.5 x 4" or 3.65 x 8"
Silver		3.65 x 4"
Bronze		3.65 x 1"

SILVER AD SIZE: 3.65 x 4

BRONZE AD SIZE: 3.65 x 1

GOLD AD SIZE: 7.5 x 4 (shown) or 3.65 x8

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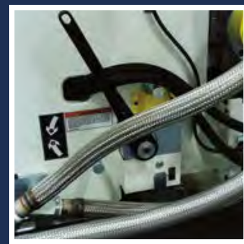

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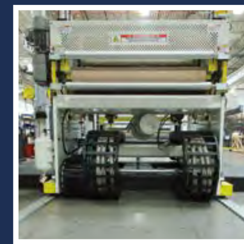

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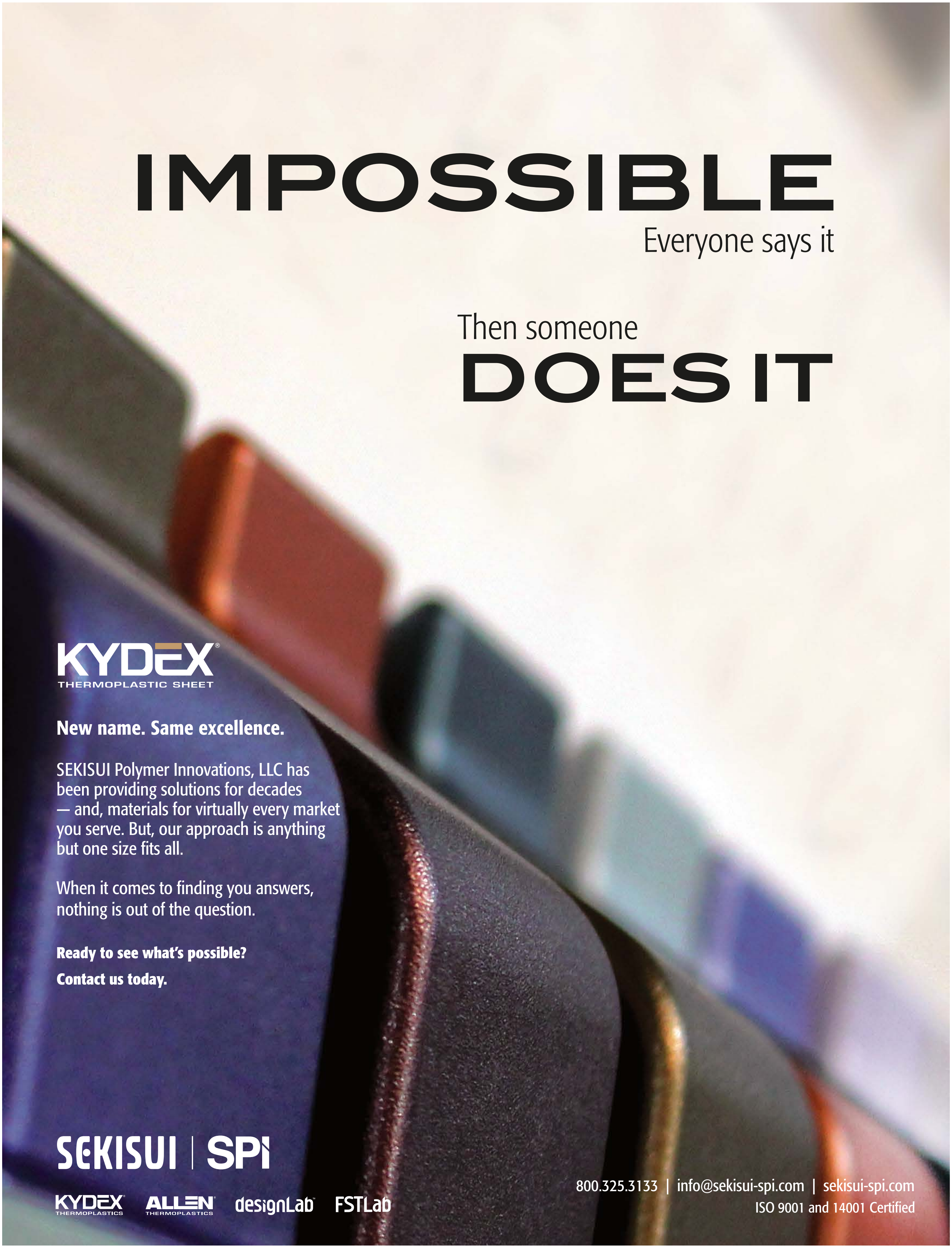
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